2.5 Effects of the Action

2.5.1 Effects of the Action on the Species

2.5.1.1 Construction Effects

2.5.1.2 Operations Effects

Water facility operations are described in the BA Section 3.3 *Operations and Maintenance of New and Existing Facilities*. Modeling methods and results simulating operations of the PA and NAA are provided in Appendix 5.A *CALSIM II Modeling and Results* and Appendix 5.B *DSM2 Modeling and Results*. For ease of reference, the proposed North Delta Diversion rules, the proposed operating criteria for the existing South Delta facilities, and existing Delta regulatory requirements that guided modeling and analysis of the proposed operations are in Appendix ##.

2.5.1.2.1 Increased Upstream Temperature

Coldwater Pool

Salmonids cannot access historical spawning grounds above the Shasta Dam and are now dependent on cold water pool releases to successfully spawn during the summer and fall. Shasta reservoir stores water for several purposes including flood control, irrigation, and water releases in dry months to prevent salt intrusion into the Delta. BOR is also responsible for providing adequate in-stream temperatures so that ESA-listed salmonids below Keswick Dam can successfully spawn each year. A temperature control device was installed in 1997 to improve downstream temperatures for ESA-listed salmonids by releasing epilimnetic waters in the winter/spring and hypolimnetic waters in the summer/fall. Management and timely distribution of the cold water stratified at the bottom of the reservoir is a critical component of temperature management of instream flows during the salmonid spawning season.

The amount of cold water pool available for instream temperature management depends on carry-over storage, reservoir water temperature, and the amount, timing, and water temperature of inflows to and outflows from Shasta Reservoir. End of September storage targets of 1.9 MAF are part of the NMFS RPA actions intended to sustain cold water supply for winter and spring run Chinook each year (NMFS 2009). This RPA has not been met during some years. Dry winters reduce the likelihood temperature compliance points needed for successful spawning can be met. Cold water pool availability involves many management decisions, so it is essential that appropriate monitoring occurs to inform when and how much water to release to protect spawning salmonids. Meeting predetermined storage targets is a tool to help ensure that enough cold water will be available, but does not take into account day-to-day operations that can compromise meeting predetermined geographic temperature compliance points in the upper Sacramento River.

Under dual conveyance of the Proposed Action (PA), reservoir water releases and, therefore, CWP availability may be changed from existing conditions for optimization of exports in the North and South Delta. If CWP storage and management is improved or degraded it could have significant effects on the viability of listed salmonids.

Temperature

Chinook salmon depend on suitable water temperatures for spawning and essentially all life functions. Chinook salmon in California are at the southern end of their range within North America. Additionally, historical habitat in the Central Valley that provided suitable summer temperatures for adult holding, spawning, and early life stages is now blocked by dams.

Salmonids in the Sacramento River are now dependent on cold water temperature management in the upper Sacramento River below Keswick Dam. Winter-run and spring-run in particular are sensitive to Keswick Reservoir water releases because they either spawn or hold in the upper Sacramento River during the summer months.

Based on several studies on Central Valley Chinook, as well as more northern races of Chinook, temperatures between 43°and 54°F (6 and 12°C) appear best suited to Chinook salmon egg and larval development (Myrick and Cech 2004). Several studies indicated that daily temperatures over 56°F (13.3°C) would lead to sub-lethal and lethal effects to incubating eggs (Seymour 1956, Boles 1988, U.S. Fish and Wildlife Service 1998, U.S. Environmental Protection Agency 2003). A 56°F (13.3°C) temperature compliance program was included in the NMFS OCAP RPA to protect the sensitive life-stages of listed Chinook salmon (NMFS 2009). Consequently, the habitat cold enough for spawning and early life stage survival changes every year in relation to where in the Sacramento River the upper temperature threshold of 56°F (13.3°C) can be maintained from May to October. Keswick and Shasta dams block salmon and steelhead from their historical habitat, confining them to a limited amount of thermally suitable habitat that varies in spatial extent within and between years.

Recently, a succession of dry years with low precipitation highlighted how difficult the upper river spawning area is to manage for successful spawning. High mortality (greater than 95 percent) in the youngest life-stages (eggs, yolk sac-fry) resulted when temperature compliance points were not maintained under 56°F (13.3°C) for the spawning season (National Marine Fisheries Service 2016e).

Recent investigations into causes of mortality upstream also revealed that the 56°F (13.3°C) daily temperature criteria mandated in the NMFS OCAP RPA was not adequate to protect the earliest life-stages. Most of the egg/fry temperature studies relied on for this threshold were conducted in a laboratory with constant temperatures. In the river, managing for a daily average temperature of 56°F (13.3°C) can still result in a maximum daily temperature of greater than 60°F (15.5°C).

EPA reviewed several studies and concluded that a temperature standard based on seven-day average daily maximum temperatures (7DADM) was better at determining suitable spawning and rearing temperatures for salmonids (U.S. Environmental Protection Agency 2003). The NMFS OCAP RPA is being reinitiated due to the unprecedented mortality for two consecutive winter-run brood years and the availability of new studies and models, including the River Assessment for Forecasting Temperature (RAFT) model. The RAFT model more accurately predicts temperatures to better manage reservoir releases to maintain suitable instream temperatures in the upper Sacramento River (Pike et al. 2013).

Every salmonid life-stage is dependent on suitable temperatures. Besides spawning and egg incubation, juvenile rearing also occurs in the upper Sacramento River. Salmonids with a stream life history, such as spring-run Chinook salmon and steelhead, need suitable spawning and rearing temperatures to be maintained year round. The larger salmonid juvenile life-stages are less sensitive to temperature then the alevins and yolk-sac fry, but will suffer lethal and sub-lethal effects when not in optimal instream temperatures. EPA guidelines recommend water temperatures do not exceed 61°F (16°C) 7DADM for juvenile rearing salmonids in the upper basin of natal rivers and not to exceed 64°F (18°C) in the lower basin of natal rivers (U.S. Environmental Protection Agency 2003). Potential sub-lethal temperature effects on juvenile salmonids include slowed growth, delayed smoltification, desmoltification, and extreme physiological changes, which can lead to disease and increased predation. There are several studies on different runs of Chinook salmon over several watersheds that seem to show acclimation of colder or warmer temperature tolerances. Several studies suggest that the optimal temperature for Chinook salmon growth lies within the 63°F-68°F (17–20°C) range, provided that food is not limiting, and other factors, such as disease, predation, and competition have a minimal effect. It is unlikely that Chinook salmon in field conditions will feed at 100 percent satiation, however, and the effects of disease, competition, and predation should also be taken into account (Myrick and Cech 2004).

Green sturgeon have different temperature requirements than salmonids in the upper Sacramento River. The majority of green sturgeon spawn above Red Bluff Diversion Dam. Suitable spawning temperatures must remain below 63°F (17.5°C) to reduce sub-lethal and lethal effects. Temperatures in the range of 57° to 62°F (14 to 17°C) appear to be optimal for embryonic development (Van Eenennaam et al. 2005). Juvenile sturgeon can tolerate higher temperatures and optimal bioenergetics performance was found to be between 59 to 66°F (15 to 19°C) (Mayfield and Cech 2004).

Reservoir releases from Keswick Reservoir influence flows and temperatures in the upper and lower Sacramento River, which is critical habitat for several ESA-listed species, including two runs (winter and spring) of Chinook salmon, Central Valley steelhead, and green sturgeon. Any change in seasonal, monthly, and daily water releases out of Shasta Dam under the PA have been analyzed for potential effects on critical habitat. Changes in release patterns expected and modeled under the dual conveyance capabilities of the PA and are addressed in this Opinion.

2.5.1.2.1.1 Winter-run Exposure and Risk

SR winter-run Chinook salmon exposure and risk to warm water temperatures occurring in the upper reaches of the Sacramento River under the PA are discussed below by life stage in the following order: (1) spawning, egg incubation and alevins, (2) fry and juvenile rearing and outmigration, and (3) adult immigration and staging.

Spawning, Egg Incubation, Alevins

Winter-run Chinook salmon eggs and alevins occur in the Sacramento River from the time when spawning begins in April, through October, with a peak during June through September (Vogel and Marine 1991). CDFW aerial redd surveys from 2003 through 2014 shows that the vast majority (99.3 percent) of SR winter-run Chinook salmon spawning occurs upstream of Airport Road Bridge (RM 284).

Modeled mean monthly water temperatures during the April through October spawning and incubation period for SR winter-run Chinook salmon are presented in the BA, Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, and

Table 5.C.7-8. Overall, the analysis in the BA demonstrates that the PA would result in a marginal increase in mean water temperatures (predominantly less than one °F) throughout the spawning reach of Keswick Dam to Red Bluff in all months of the spawning and incubation period and water year types. The largest increase in mean monthly water temperatures under the PA relative to the NAA would be 0.6°F, or up to 1.1 percent, and would occur at Red Bluff in above normal water years during August and in above- and below-normal years during September; and at Bend Bridge in below normal years during September. These largest increases would occur during the period of peak presence of spawners, eggs, and alevins.

The BA also examined exceedence plots of monthly mean water temperatures during each month throughout the spawning and incubation period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The BA shows that the values for the PA in these exceedence plots generally track those of the NAA. Further examination of above normal water years during August (Figure Error**! No text of specified style in document.**-1) and September

Figure **Error! No text of specified style in document.**-2) at Red Bluff, below normal years during September at Red Bluff (Figure **Error! No text of specified style in document.**-3), and in below normal years during September at Bend Bridge (Figure **Error! No text of specified style in document.**-4)—where the largest increases in mean monthly water temperatures were modeled—reveals that there is a general trend towards marginally higher temperatures under the PA.

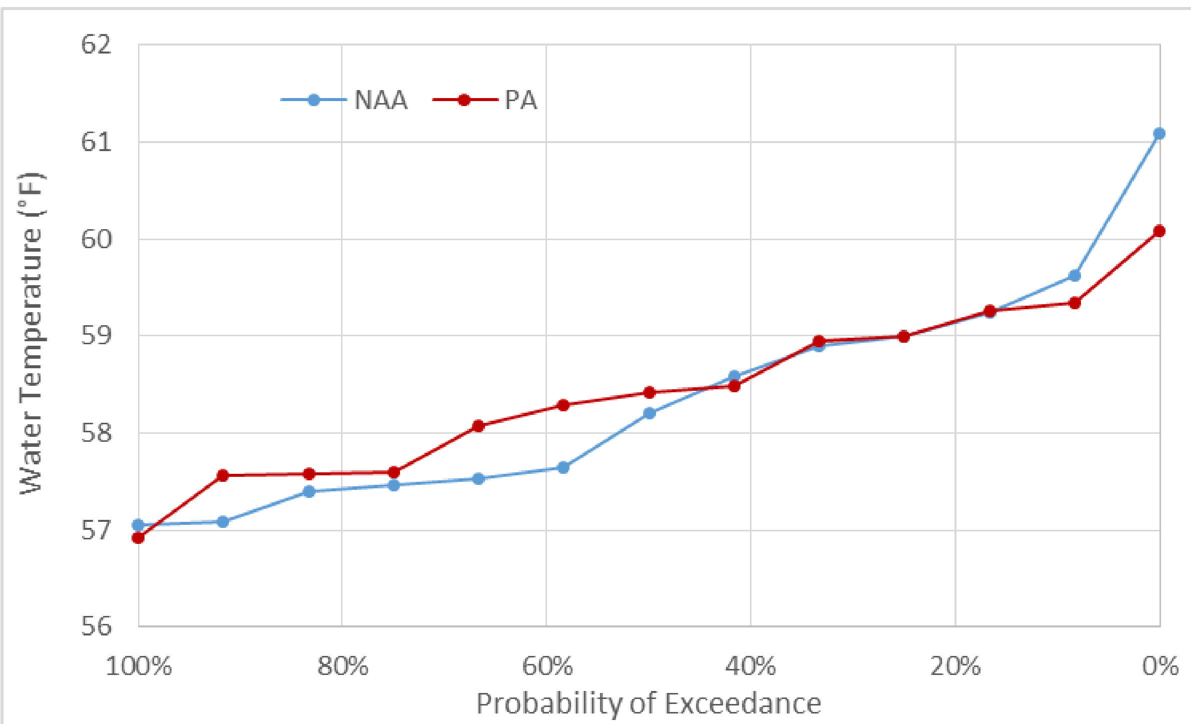

*Figure **Error! No text of specified style in document.**-1. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Above Normal Water Years*

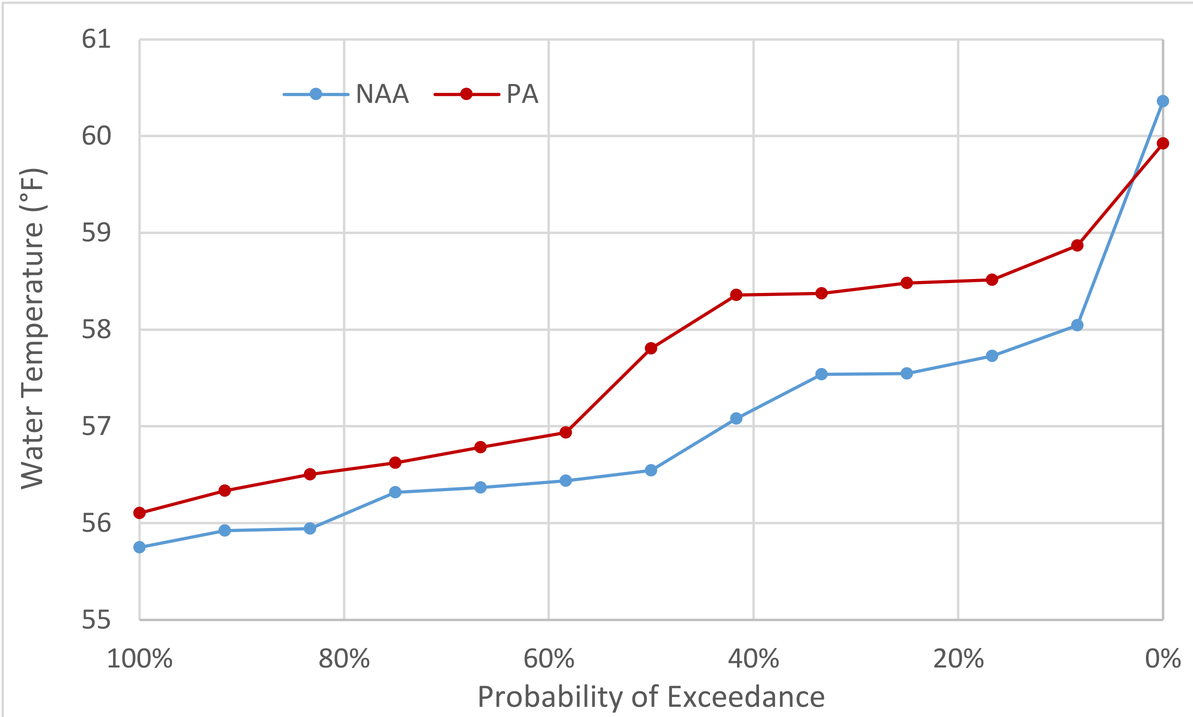

*Figure **Error! No text of specified style in document.**-2. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Above Normal Water Years*

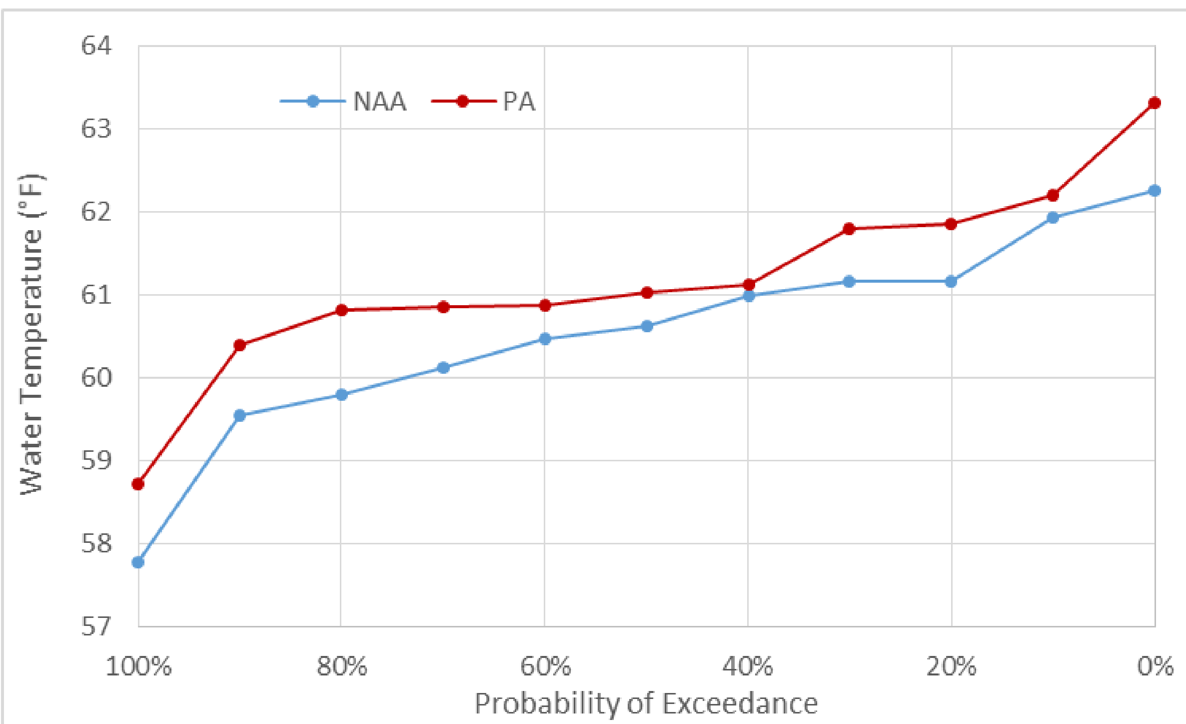

*Figure **Error! No text of specified style in document.**-3. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Below Normal Water Years*

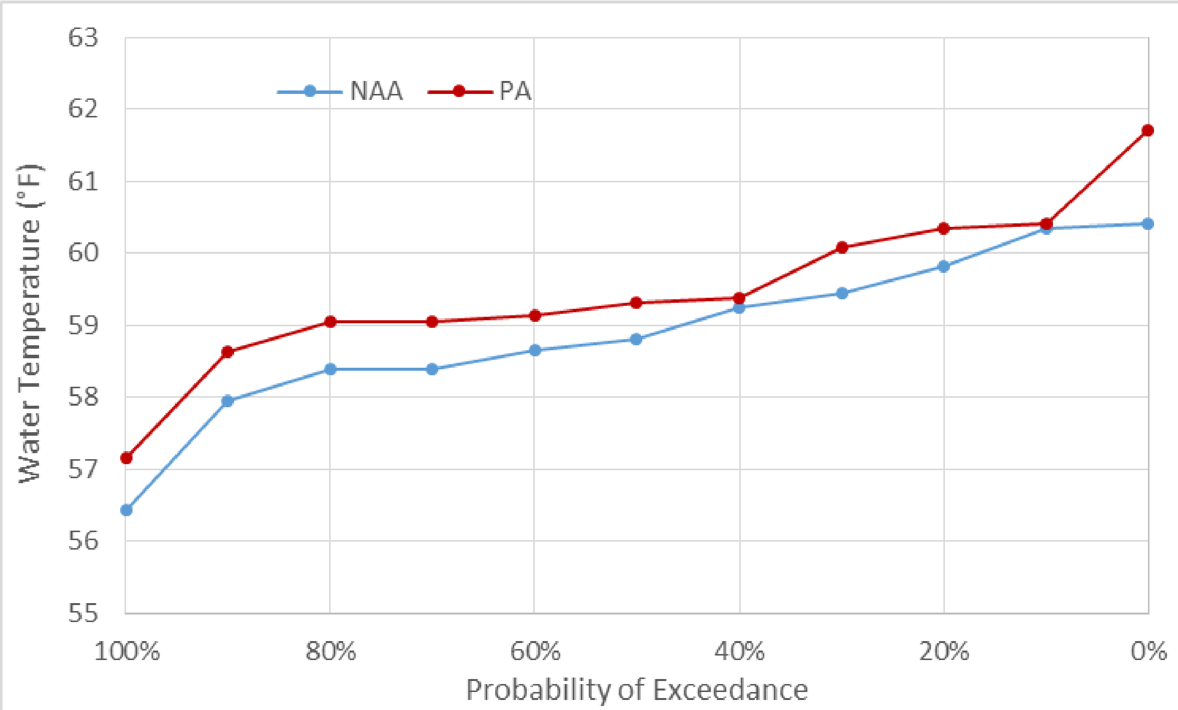

Figure ***Error! No text of specified style in document.****-4. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in September of Below Normal Water Years*

The water temperature thresholds analysis presented in the BA indicates that water temperatures under the PA are not expected to have a biologically meaningful effect on winter-run Chinook salmon spawning, egg incubation, and alevin development when compared to the NAA. Results of the water temperature thresholds analysis may be found in the BA, Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-63 through Table 5.D-67.

Overall, the thresholds analysis presented in the BA indicates that there would be more exceedances (five percent or greater) under the PA in certain months and water year types compared to the NAA. In the BA, biologically meaningful is defined as a five-percent change in the frequency of exceedance and where the difference between NAA and PA in average daily exceedance is greater than 0.5°F. In all but two cases, these exceedances would not result in biologically meaningful water temperature-related effects on winter-run spawning, egg incubation, and alevins. The two cases where modeled water temperatures under the PA would be considered biologically meaningful compared to the NAA (May of below normal water years at Clear Creek and Balls Ferry) appear to be the result of an anomalous CALSIM output from a single year (1923) in which water temperature would be substantially higher than expected (approximately 2 to 3°F).

The BA also provides SALMOD model results that predict a beneficial effect of the PA, relative to the NAA, related to the water-temperature-related mortality of SR winter-run Chinook salmon spawning, eggs, and alevins in the Sacramento River. SALMOD differentiates the water-temperature-related mortality of winter-run spawning, eggs, and alevins between pre-spawn (in vivo, or in the mother before spawning) and egg (in the gravel) mortality (see BA Attachment 5.D.2, SALMOD Model, for a full description).

Table 5.4-38 presents results for water-temperature-related mortality of spawning, eggs, and alevins, in addition to other sources of mortality for SR winter-run Chinook salmon predicted by SALMOD and discussed in section *2.5.1.2.2 Redd Dewatering*.

Table ***Error! No text of specified style in document.****-1. Table 5.4-38*

Analysis Period	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing									Grand Total
	Temperature-Related Mortality			Flow-Related Mortality			Life Stage Total	Temperature-Related Mortality				Flow-Related Mortality				Life Stage Total	
	Pre-Spawn	Eggs	Subtotal	Incubation	Super-imposition	Subtotal		Fry	Pre-smolt	Immature Smolt	Subtotal	Fry	Pre-smolt	Immature Smolt	Subtotal		
All Water Year Types[2]																	
NAA	9,092	423,231	432,323	368,939	0	368,939	801,262	5,343	2,391	0	7,734	123,789	115	0	123,904	131,638	932,900
PA	9,119	391,450	400,568	430,651	0	430,651	831,220	5,495	2,125	0	7,620	120,680	104	0	120,784	128,404	959,624
Difference	27	-31,781	-31,755	61,712	0	61,712	29,958	152	-266	0	-114	-3,109	-11	0	-3,120	-3,234	26,723
Percent Difference[3]	0	-8	-7	17	0	17	4	3	-11	0	-1	-3	-10	0	-3	-2	3
Water Year Types[4]																	
Wet (32.5%)																	
NAA	8,774	806	9,580	167,602	0	167,602	177,182	0	0	0	0	173,745	36	0	173,781	173,781	350,962
PA	8,890	670	9,560	244,211	0	244,211	253,771	0	0	0	0	154,086	27	0	154,113	154,113	407,884
Difference	116	-136	-19	76,609	0	76,609	76,589	0	0	0	0	-19,659	-9	0	-19,667	-19,667	56,922
Percent Difference	1	-17	0	46	0	46	43	0	0	0	NA	-11	-25	0	-11	-11	16
Above Normal (12.5%)																	
NAA	9,001	457	9,459	316,112	0	316,112	325,570	0	0	0	0	159,631	24	0	159,655	159,655	485,225
PA	9,001	376	9,378	369,936	0	369,936	379,313	0	0	0	0	139,838	16	0	139,854	139,854	519,167
Difference	0	-81	-81	53,824	0	53,824	53,743	0	0	0	0	-19,793	-8	0	-19,801	-19,801	33,942
Percent Difference	0	-18	-1	17	0	17	17	0	0	0	NA	-12	-32	0	-12	-12	7
Below Normal (17.5%)																	
NAA	7,909	8,021	15,930	587,438	0	587,438	603,368	10	1	0	11	95,189	127	0	95,316	95,327	698,696
PA	8,455	12,730	21,184	714,331	0	714,331	735,515	11	1	0	12	105,939	117	0	106,056	106,068	841,584
Difference	545	4,709	5,254	126,893	0	126,893	132,147	1	0	0	1	10,749	-10	0	10,740	10,741	142,888
Percent Difference	7	59	33	22	0	22	22	15	-8	0	12	11	-8	0	11	11	20
Dry (22.5%)																	
NAA	9,789	29,678	39,467	610,519	0	610,519	649,986	24	6	0	30	106,542	246	0	106,788	106,818	756,803
PA	9,474	21,650	31,123	648,552	0	648,552	679,676	25	4	0	29	122,973	182	0	123,155	123,184	802,859
Difference	-316	-8,028	-8,344	38,034	0	38,034	29,690	1	-2	0	-1	16,431	-64	0	16,367	16,366	46,056
Percent Difference	-3	-27	-21	6	0	6	5	5	-33	0	-3	15	-26	0	15	15	6
Critical (15%)																	
NAA	9,853	2,764,994	2,774,847	275,207	0	275,207	3,050,054	35,573	15,929	0	51,502	33,235	160	0	33,395	84,897	3,134,950
PA	9,779	2,561,888	2,571,667	290,273	0	290,273	2,861,940	36,581	14,162	0	50,743	39,024	223	0	39,247	89,990	2,951,930
Difference	-74	-203,106	-203,180	15,066	0	15,066	-188,113	1,008	-1,767	0	-759	5,789	63	0	5,852	5,093	-183,021
Percent Difference	-1	-7	-7	5	0	5	-6	3	-11	0	-1	17	40	0	18	6	-6

[1] Mortality values do not include base mortality
[2] Based on the 80-year simulation period
[3] Relative difference of the Annual average
[4] As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (State Water Resources Control Board 1995). Water years may not correspond to the biological years in SALMOD.

These results indicate that, combining all water year types, there would be no increase in temperature-related mortality of winter-run Chinook salmon spawning, eggs, and alevins under the PA relative to the NAA and, in fact, average annual mortality would decrease by 31,755 fish, or seven percent, under the PA. For individual water year types, only the below normal water years show an increase in pre-spawn and egg temperature-related mortality under the PA. For all other year types, average annual mortality is found to decrease under the PA and compared to the NAA. In absolute terms, most of the temperature-related mortality (greater than 95 percent) is predicted to occur in critical years. In this water year type, mortality would average 203,180 fish (seven percent) lower under the PA relative to the NAA.

Besides the two biological analyses presented in the BA, the water temperature thresholds analysis and SALMOD, NMFS' Southwest Fisheries Science Center has developed a novel egg mortality model (Martin et al. 2016) to discern how water temperatures are expected to affect Chinook salmon egg survival. The SWFSC's egg mortality model is a temperature-dependent mortality model for Chinook salmon embryos that differs from previous models in that thermal tolerance parameters were estimated using field egg-to-fry survival data, rather than assuming thermal tolerance parameters measured in laboratory studies hold in the field. Based on their analysis for field data, Martin et al. 2016 found strong evidence that significant thermal mortality occurred during the embryonic stage in some years due to a >5°F reduction in thermal tolerance in the field compared to laboratory studies. Martin et al. 2016 used a biophysical model of oxygen supply and demand to demonstrate that such discrepancies in thermal tolerance could arise to differences in oxygen supply in lab and field contexts. Because oxygen diffuses slowly in water, as embryos consume oxygen they deplete the concentration of oxygen in the surrounding water, reducing their rate of oxygen supply. This is exacerbated in warm waters because oxygen demand increases exponentially with temperature. Flowing water replenishes oxygen through convective transfer, and thereby increases oxygen supply. Thus, higher flows deliver more oxygen to embryos than low flows allowing for higher thermal tolerance. The egg survival-temperature relationships found in laboratory studies likely overestimate thermal tolerance of eggs developing in the river by roughly 3°C because those studies typically take place at relatively high flows compared to flows experienced by eggs in spawning gravels in the river (Martin et al. 2016).

In laboratory studies, Chinook salmon embryos have been allowed to develop in highly oxygenated, fast flowing water (approximately 0.15 cm/s; Beacham and Murray 1989, Jensen and Groot 1991, U.S. Fish and Wildlife Service 1999), while in nature, embryos are embedded in gravel where flow velocities are lower [~0.04 cm/s; (Zimmermann and Lapointe 2005)]. By accounting for oxygen supply and demand in the relationship between egg survival and water temperature, the SWFSC's egg mortality model represents the best available tool for estimating the thermal risk to Chinook salmon eggs under the PA. Using the SWFSC egg mortality model linked with a 1-dimensional temperature model of the Sacramento River at 1km spatial resolution (Pike et al. 2013), survival probabilities are estimated for eggs exposed to water temperatures under the PA and NAA.

The SWFSC's egg mortality model shows the winter-run Chinook salmon egg survival probability under the PA and NAA for all water years combined and by individual water year type (Figure X1). These results show the influence of temperature on survival independent of other sources of mortality. Other factors affecting egg and alevin survival such as physical disturbance from redd superimposition would lower the overall survival, beyond that which is described as water temperature dependent survival shown in Figure X1. The mean water temperature dependent survival probability under the PA ranged from 20 percent in critical years to 95 percent in above normal years; and the mean for all water years combined was 76. This means that in critical years 80 percent of egg and alevin mortality is attributable to temperatures, while only 5 percent of egg and alevin mortality is expected to be caused by temperatures in above normal years.

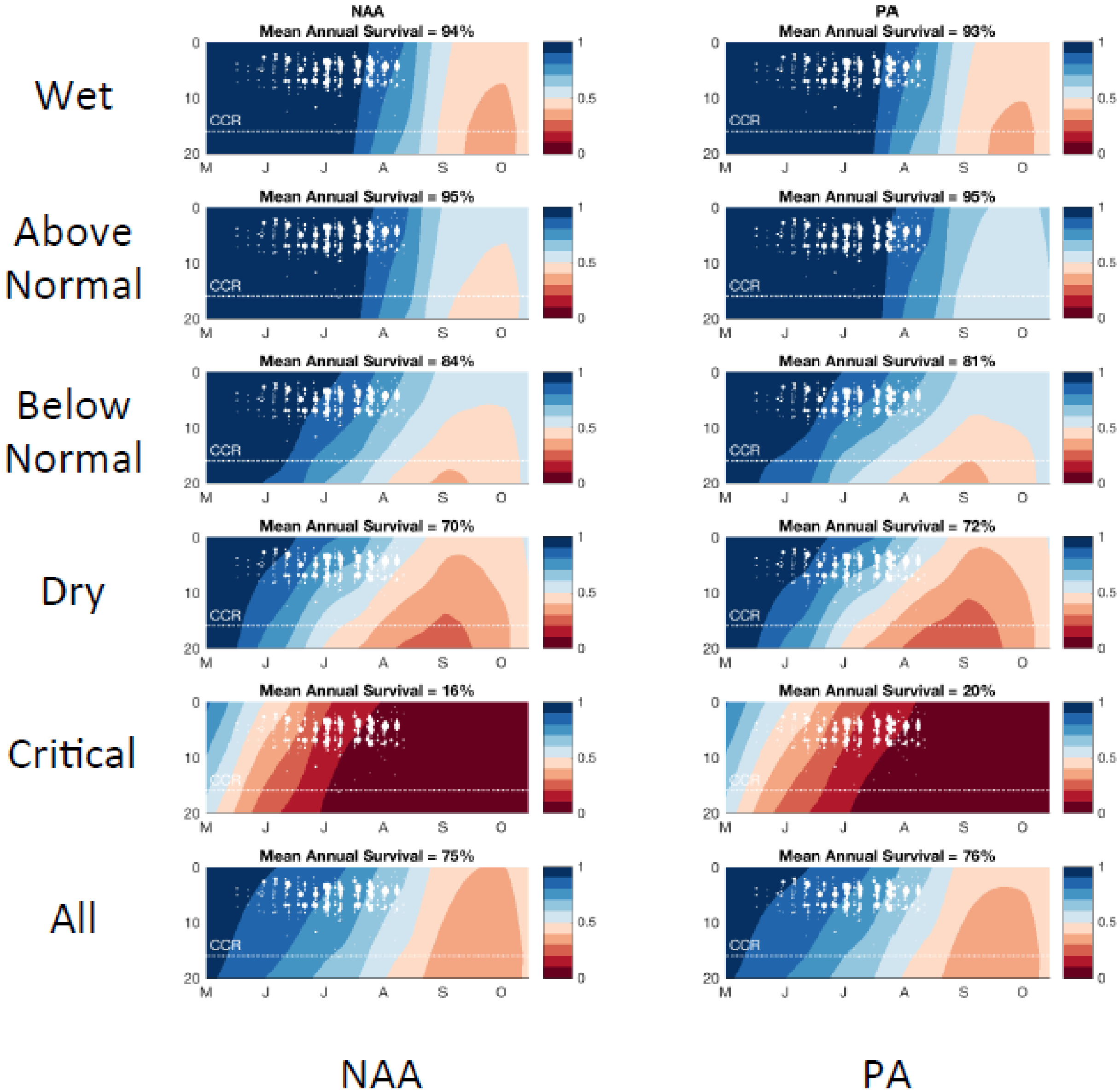

Figure X1. Winter-run Chinook salmon egg survival landscape from the SWFSC's temperature dependent egg survival model. Primary Y-axis is distance in km downstream from Keswick Dam. The color key is the probability of survival. Winter-run redds during the 2012-2015 spawning seasons (white marks) were used to calculate mean annual survival under the NAA and PA.

A comparison of temperature dependent egg survival between the PA and NAA shows little to no difference between the alternatives. Mean annual temperature-dependent survival would decrease under the PA by one percent in wet years and three percent in below normal years. For the other water year types and for all water years combined, the SWFSC's model showed no difference in mean annual temperature-dependent survival between the PA and NAA or slightly higher survival under the PA. All differences in mean annual temperature-dependent survival are likely within the margin of error of the model and are not significant.

The SWFSC model results suggest that winter-run Chinook salmon egg survival will largely be the same under the NAA and PA operations – both alternatives are likely to result in adverse effects, particularly in drier water years.

Overall, the certainty of the three biological tools' respective ability to accurately estimate thermal impacts to eggs and alevins in the Sacramento River under the PA is low[1] because all three models utilize daily (thresholds analysis and the SWFSC' egg/alevin mortality model) or weekly (SALMOD) water temperatures downscaled from the same modeled monthly values. Eggs and alevins developing in the Sacramento River spawning gravels experience a thermal regime that varies between day and night and from one day to the next. The downscaled water temperature modeling utilized in all the biological models does not capture that level of thermal variation. Nevertheless, the biological models are useful qualitative indicators of potential thermal impacts under the PA.

Fry and Juvenile Rearing and Outmigration

Modeled mean monthly water temperatures during the July through November juvenile rearing period for winter-run Chinook salmon in the Sacramento River upstream of the Delta show a marginal difference between the NAA and the BA (see BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10). Overall, the PA would change mean water temperatures very little (less than 1°F or approximately one percent) throughout the juvenile rearing reach of Keswick Dam to Knights Landing in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F (1.4 percent) and would occur at Knights Landing in below normal years during August.

Further examination of below normal water years in August at Knights Landing, where the largest increase in mean monthly water temperature was seen, indicates that water temperatures under the PA would be higher than those under NAA for most of the exceedance range by up to approximately 2.2°F, particularly in the colder end of the range (BA Figure 5.4 109). The temperature threshold analysis results predict that those temperatures for Knights Landing during August of below normal water years would be greater than the 64°F 7DADM threshold on 100 percent of days under both the NAA and PA. These results suggest that conditions are already unsuitable for winter-run Chinook salmon fry and juvenile rearing under the NAA and that these temperatures would have an adverse effect.

For the water temperature thresholds analysis in the BA, the period of July through March was evaluated. The threshold used was the USEPA's 7DADM value of 61°F for the core juvenile rearing reach from Keswick Dam to Red Bluff and 64°F for the non-core juvenile rearing reach at Knights Landing (see BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49). The 7DADM values were converted by month to function with daily model outputs (see BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51). Results of the water temperature thresholds analysis indicate that an adverse effect to winter-run Chinook salmon juveniles is expected under the PA's thermal regime (Tables 5.D-68 through 5.D-73).

[1] Additional key assumptions and data limitations that influence the reliability of results from SALMOD are highlighted in NRC (2010).

The general pattern is that daily occurrences of threshold exceedances under the PA decrease from Keswick Dam to Bend Bridge, especially critical years early in the rearing season (September through October). As such, the frequency of adverse effects to winter-run Chinook salmon juveniles is not found to increase, but, on average, temperature exceedances tended to be more severe.

From Bend Bridge downstream to Red Bluff, the percent of days exceeding the 61°F 7DADM threshold under the PA would be more than five percent higher in certain months of critical, dry, and below normal water years. For this reach and for these months, however, there was not a corresponding more-than-0.5°F difference in the magnitude of average daily exceedance under the PA. This means that while the frequency of exceedance is expected to increase, the magnitude is expected to be minor relative to the NAA.

From Red Bluff to Knights Landing, the percent of days exceeding the 64°F 7DADM threshold for non-core rearing and emigration habitat under the PA would be more than five percent higher than under the NAA in certain months and water year types. For this reach and for these months, however, there was not a corresponding more-than-0.5°F difference in the magnitude of average daily exceedance under the PA. This means that while the frequency of exceedance is expected to increase, the magnitude is expected to be minor relative to the NAA.

The SALMOD model provides predicted water-temperature-related fry and juvenile winter-run Chinook salmon mortality, which is a combination of mortality of the fry, pre-smolt, and immature smolt life stages (see BA Attachment 5.D.2, SALMOD Model, for a full description). Results for water temperature-related mortality of these life stages are presented in Table 5.4 38 and the annual exceedance plot for all water year types combined is presented in Figure 5.4 110. These results indicate that differences under the PA in temperature-related mortality relative to the NAA would generally be insignificant. The mean annual temperature-induced mortality for all water years and for the NAA is about 7,734 fish (or 5.9 percent of total fry and juvenile rearing mortality). Accordingly, the mean annual temperature-induced mortality for all water years and for the PA is about 7,620 fish (or 5.9 percent of total fry and juvenile rearing mortality). These results indicate that the PA would not increase water temperature-related mortality of fry and juvenile winter-run Chinook salmon relative to the NAA, but that temperatures play a significant role in fry and juvenile rearing mortality.

Adult Immigration and Holding

Mean monthly water temperatures were evaluated in the BA for the Sacramento River at Keswick, Bend Bridge, and Red Bluff during the December through August adult immigration period for winter-run Chinook salmon. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) at these locations in all months and water year types in the period (see BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.3.7-7, Table 5.C.7-8).

The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F (0.9 percent) and would occur at Red Bluff in below normal years during August.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the juvenile emigration period (see BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure

5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. For below normal water years in August at Red Bluff, where the largest increases in mean monthly water temperatures were seen, the PA curve is consistently higher than the NAA curve by approximately 0.5°F (BA Figure 5.4 111). As indicated in the threshold analysis, temperatures predicted at Red Bluff during August of below normal water years would be lower than the 68°F 7DADM for all days in both the NAA and PA and, therefore, there would be no biologically meaningful effect on winter-run Chinook salmon adult immigrants moving through the Red Bluff area. Overall, the analysis in the BA shows that there would be more exceedances (five percent or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on adult immigrants.

To evaluate water temperature threshold exceedance during the adult holding life stage at Keswick Dam, Balls Ferry, and Red Bluff, the USEPA's 7DADM threshold value of 61°F was used (see BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49) (U.S. Environmental Protection Agency 2003). Overall, the thresholds analysis in the BA indicates that there would be more exceedances (five percent or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on holding adults.

2.5.1.2.1.2 Spring-run Exposure and Risk

Spring-run Chinook salmon exposure and risk to warm water temperatures occurring in the upper Sacramento River under the PA are discussed below by life stage in the following order: (1) spawning, egg incubation, and alevin development; (2) fry and juvenile rearing and outmigration; and (3) adult immigration and holding.

Spawning, Egg Incubation, and Alevin Development

Aerial redd surveys in September have identified likely spring-run Chinook salmon spawning in the upper Sacramento River (CDFW unpublished data 2016). Total redds by reach from 2001 to 2016 are shown in Table **Error! No text of specified style in document.**-2 below. The eight most recent years of observations (2009 to 2016), were very low, with numbers of redd observations near zero (with the exception of 57 redds in 2013), and in three of the years no surveys were completed. The highest density of spring-run Chinook salmon redds occur between ACID Dam to Airport Road Bridge. Spring-run eggs and alevin remain in the gravel from the time when spawning begins in September through fry emergence Dec/Jan.

*Table **Error! No text of specified style in document.**-2. Spatial Distribution of Spawning Redds in the Sacramento River Based on Aerial Redd Surveys in September, 2001-2016 (source CDFW unpub)*

Reach	Mean Annual Percent of Total Redds Sighted	Total Redds
Keswick to ACID Dam	12.4	56
ACID Dam to Highway 44 Bridge	32.8	108
Highway 44 Bridge to Airport Road Bridge	27.7	141
Airport Rd. Bridge to Balls Ferry Bridge	10.9	48
Balls Ferry Bridge to Battle Creek	7.3	29
Battle Creek to Jelly's Ferry Bridge	1.5	35
Jelly's Ferry Bridge to Bend Bridge	2.6	10
Bend Bridge to Red Bluff Diversion Dam	0.8	2
Below Red Bluff Diversion Dam	4.1	21
ACID = Anderson-Cottonwood Irrigation District		

Modeled mean monthly water temperatures during the August through December spawning, egg incubation, and alevins period for spring-run Chinook salmon are presented in the BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. As stated in the BA, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately one percent) from Keswick Dam to Red Bluff in all months of the period and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, or up to 1.1 percent, and would occur at Red Bluff in above normal years during August, and above- and below-normal years during September, and at Bend Bridge in below normal years during September. The increases during September would occur during the period of peak presence of spawners, eggs, and alevins.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7).

The values for the PA in these exceedance plots generally overlap those of the NAA. Further examination of above normal water years—during August (BA Figure 5.4-59) and September (BA Figure 5.4-60) at Red Bluff, below normal years during September at Red Bluff (BA Figure 5.4-61), and below-normal years during September at Bend Bridge (Figure 5.4-62) where the largest increases in mean monthly water temperatures were found, reveals that water temperatures under the PA are almost always slightly warmer than under the NAA, with typically less than a degree (˚F) difference between the two alternatives.

The water temperature exceedance plots are useful for assessing whether the PA is expected to make conditions warmer, colder, or have little impact relative to the NAA. The plots clearly show that the latter (little impact) is the case. What the plots do not show is how fish life stages, in this case spring-run Chinook salmon eggs and alevins, will be affected by the PA thermal regime.

The SWFSC egg mortality model, described above in the winter-run Chinook salmon section, was linked with a 1-dimensional temperature model of the Sacramento River with one kilometer (km) spatial resolution (Pike et al. 2013) to estimate daily survival probabilities for eggs when exposed to water temperatures under the PA and NAA. Figure X3 shows the spring-run Chinook salmon egg survival probability under the PA and NAA for all water years combined and by water year type. These results show the survival after accounting for only the effects of water temperature. Other factors affecting egg and alevin survival such as physical disturbance from redd superimposition would lower the water temperature dependent survival shown in Figure X3.

Spring-run Chinook salmon egg survival is expected to be less than 50% throughout much of the first 20 km of spawning habitat in September and early October for all water years combined and in all water year types except for above normal years under either alternative. In critical water years, egg survival would be less than 10% throughout the spawning habitat for all of August, September, and the first half of October. These results suggest that Sacramento River water temperatures under the PA or the NAA will have an adverse effect on spring-run Chinook salmon egg incubation.

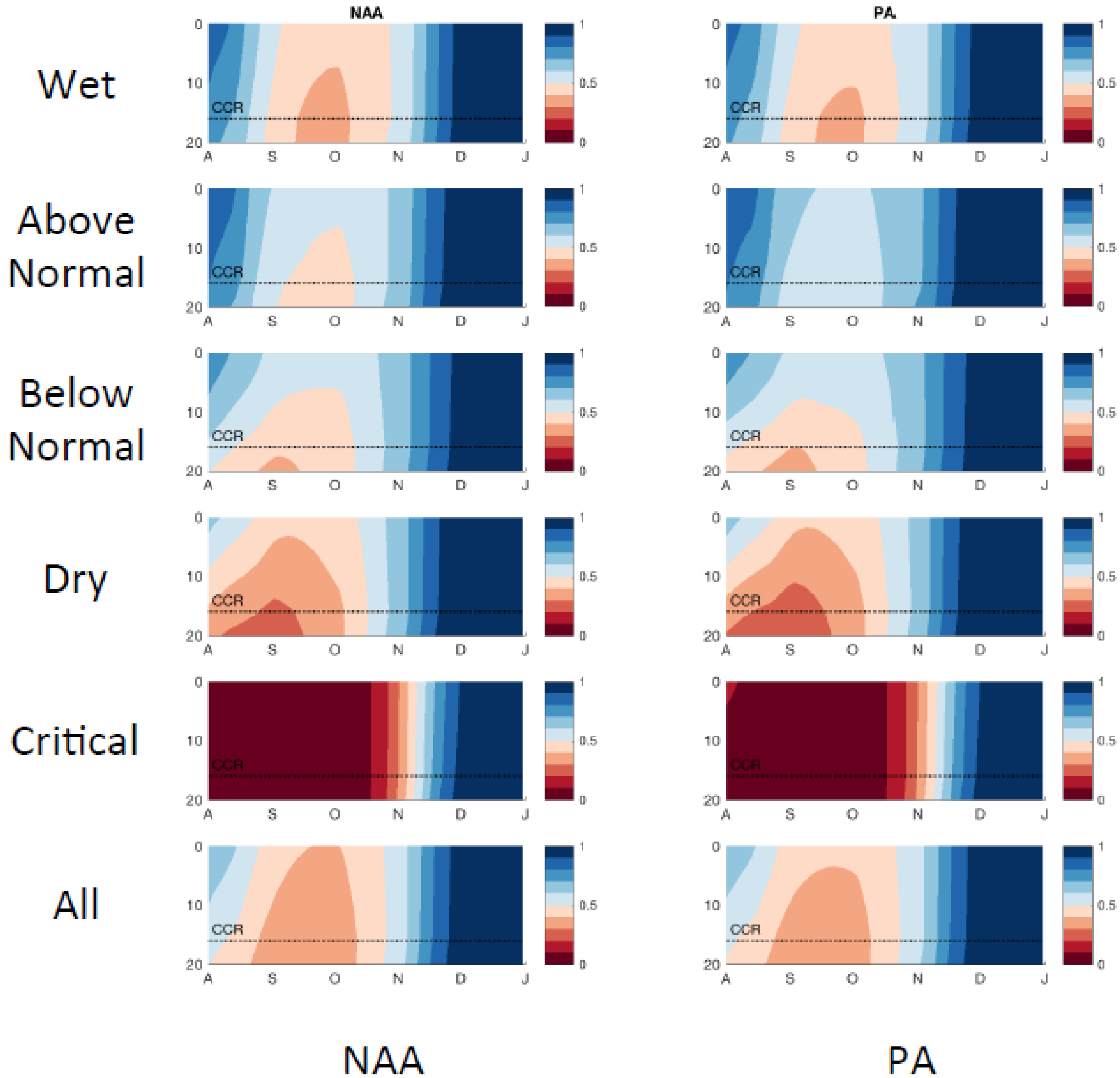

Figure X3. Spring-run Chinook salmon egg survival landscape from the SWFSC's temperature dependent egg survival model. Primary Y-axis is distance in km downstream from Keswick Dam. The color key is the probability of survival.

To evaluate water temperature threshold exceedance during the spawning, egg incubation, and alevin life stages between Keswick Dam and Red Bluff, the USEPA's 7DADM threshold value of 55.4°F was used (Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-51).

Overall, the thresholds analysis indicates that there would be more exceedances (five percent or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on spawning, egg incubation, and alevins.

The Reclamation Egg Mortality Model provides temperature-related estimates of spring-run egg mortality in the Sacramento River (see Appendix 5.D, Attachment 1, *Reclamation Egg Mortality Model*, for full model description). As noted in Appendix 5.D, Section 5.D.2.1. *Water Temperature Analysis Methods*, NMFS believes this model underestimates temperature-related mortality and likely is not sensitive enough to capture small differences in scenarios or temperature-related mortality experienced by recent winter-run brood years and, as a result, should be viewed with caution until a more accurate model is developed or there is better understanding of temperature effects on juvenile production. Because of this and the fact that the egg life stage has the highest potential effect on the propagation of population size in a life cycle context, a conservative value of a more-than-two-percent change in percent of total individuals (on a raw scale) was defined as a biologically meaningful effect for Reclamation Egg Mortality Model results (see Appendix 5.D, Section 5.D.2.1.2.3, *Reclamation Egg Mortality Model*, for details). Results of the model are presented in Table 5.4-55 and Figure 5.4-138 through Figure 5.4-143.

Results indicate that there would be no large increases in egg mortality under the PA relative to the NAA. The largest increase in mean egg mortality would be 1.9 percent (raw difference) in below-normal water years. There would be a biologically meaningful reduction in egg mortality of 6.7 percent in critical water years, although this difference in means is driven largely by two years in which egg mortality would be substantially (35 to 45 percent) reduced under the PA relative to the NAA (Figure 5.4-142).

The SALMOD model provides predicted water temperature-related mortality of spring-run Chinook salmon spawning, eggs, and alevins the Sacramento River. This water temperature-related mortality of the combined spring-run Chinook salmon “spawning, eggs, and alevins” life stage is split up as *pre-spawn* (in vivo, or in the mother before spawning) and *egg* (in the gravel) mortality. The annual exceedance plot of temperature-related mortality of spring-run Chinook salmon spawning, eggs, and alevins is presented in Figure 5.4-144. The model indicates that combining all water year types, water temperature-related mortality of the spawning, egg, and alevin life stage would decrease by 12,110 fish (7 percent) under the PA relative to the NAA.

Within the combined spawning, egg, and alevin life stage, there would be an increase in prespawn mortality of 4,431 eggs in the mother (10 percent) under the PA, but a decrease in egg mortality of 16,540 eggs (13 percent). Water-temperature-related mortality of this combined spawning, egg, and alevin life stage would comprise the large majority (more than 95 percent) of overall spring-run Chinook salmon mortality and, therefore, can be considered an important source of mortality to early life stages of spring-run Chinook salmon. Individual water year types largely follow the same patterns as for all water year types combined, with few exceptions. Most notably, in below normal years, there would be an overall increase in water-temperature-related mortality under the PA in both pre-spawn (100 percent) and egg (18 percent) mortality, and an overall increase in water temperature-related mortality under the PA (18 percent).

Fry and Juvenile Rearing and Outmigration

Modeled mean monthly water temperatures during the year-round fry and juvenile rearing period for spring-run Chinook salmon in the Sacramento River upstream of the Delta (Table 5.4-27) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10[53].

Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately one percent) throughout the juvenile rearing reach of Keswick Dam to Knights Landing in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F (1.4 percent), and would occur at Knights Landing in below normal years during August.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the juvenile rearing period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.10-7[54]).

The values for the PA in these exceedance plots generally match those of the NAA. Further examination of below normal water years in August at Knights Landing, where the largest increase in mean monthly water temperature was seen, indicates that water temperatures under the PA would be higher than those under NAA for most of the exceedance range by up to approximately 2.2°F, particularly in the colder end of the range (Figure 5.4-108). As indicated below in the threshold analysis, temperatures predicted for Knights Landing during August of below normal water years would be greater than the 64°F 7DADM threshold on 100 percent of days under both the NAA and PA, although there is low certainty that modeled values are comparable to actual values. Therefore, this suggests that, with low certainty, conditions would already be unsuitable for spring-run Chinook salmon fry and juvenile rearing for reasons that are independent of the PA.

For purposes of this analysis, the water temperature thresholds analysis for juvenile rearing and emigration were combined and the year-round period was evaluated. For juvenile rearing and emigration, the thresholds used were from the USEPA's 7DADM value of 61°F for core juvenile rearing reach from Keswick Dam to Red Bluff and 64°F for the non-core juvenile rearing reach at Knights Landing (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49). The 7DADM values were converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51). Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-85 through 5.D-90.

At Keswick Dam, there would be no months or water year types in which there would be five percent more days under the PA compared to the NAA in which temperatures would exceed the threshold (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-85). There would be two instances in which average daily exceedance would be 0.5°F: September of critical years and September for all water year types combined (reflecting that the only differences in threshold exceedance among water year types during September would occur during critical years). There would be no concurrent increase, however, in the percent of days exceeding the threshold in these instances. This indicates that the frequency of days above the threshold be would similar under the PA, but exceedances would be higher on average.

Overall, the thresholds analysis indicates that there would be more exceedances (five percent or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on spring-run Chinook salmon fry and juvenile rearing, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta* and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. This analysis also does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival.

This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. Although the process targets winter-run Chinook salmon, these changes are expected to benefit other races of Chinook salmon. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

The SALMOD model provides predicted water temperature-related fry and juvenile spring-run Chinook salmon mortality, which is a combination of mortality of the fry, pre-smolt, and immature smolt life stages (see Attachment 5.D.2, *SALMOD Model*, for a full description).

Results for water temperature-related mortality of these life stages are presented in Table 5.4-55 and the annual exceedance plot is presented in Figure 5.4-182. These results indicate that there would be very little water temperature-related mortality to these life stages. Therefore, there would be no biologically meaningful effect of the PA.

Adult Immigration and Holding

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Bend Bridge, and Red Bluff during the March through September adult immigration period for spring-run Chinook salmon (Table 5.4-27) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F (0.9 percent to 1.1 percent), and would occur at Red Bluff in below normal years during August and in above- and below normal water years during September.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult immigration period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The curves for the PA generally match those of the NAA.

For below normal water years in August at Red Bluff, where the largest increase in mean monthly water temperature was seen, the PA curve is consistently higher than the NAA curve by approximately 0.5°F (Figure 5.4-111). During September of above normal and below normal water years, water temperatures are more variable between the two scenarios, but those under the PA are higher in nearly all years (Figure 5.4-60, Figure 5.4-61).

To evaluate water temperature threshold exceedance during the adult immigration life stage at Keswick Dam, Bend Bridge, and Red Bluff, the USEPA's 7DADM threshold value of 68°F was used (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods,* Table 5.D.2-49). The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D.2-51). Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-91 through 5.D-93.

At Keswick Dam and Red Bluff, there would be no months or water year types in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-91 and Table 5.D-93).

At Bend Bridge, there are two instances during which the percent of days exceeding the 68°F DADM under the PA would be more than 5 percent higher than under the NAA: August of critical water years (5.1 percent higher under the PA) and September of critical water years (5.3 percent higher) (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results,* Table 5.D-92). However, there would be an insignificant (less than 0.1°F) difference in average daily exceedance in these instances. Therefore, it was concluded that there would be no biologically meaningful effect on spring-run adult immigration.

Overall, the thresholds analysis indicates that there would be more exceedances (5 percent or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on winter-run Chinook salmon adult immigration, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process,* that would be used to avoid and minimize any modeled effects. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Balls Ferry, and Red Bluff during the April through September adult holding period for spring-run Chinook salmon (Table 5.4-27) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results,* Section 5.C.7, *Upstream Water Temperature Modeling Results.* Table 5.C.7-3, Table 5.C.7-5, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, or up to 1.1 percent, and would occur at Red Bluff in above normal years during August and above- and below normal years during September. This 0.6°F increase during August would occur during the last month of the peak adult holding period (May through August).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult holding period (Appendix 5.C, *Upstream Water Temperature Methods and*

Results, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.5-7, Figure 5.C.7.8-7). The curves for PA generally match those of the NAA. For below normal water years in August at Red Bluff, where the largest increase in mean monthly water temperature was seen, the PA curve is consistently higher than the NAA curve by approximately 0.5°F (Figure 5.4-111).

To evaluate water temperature threshold exceedance during the spring-run Chinook salmon adult holding life stage at Keswick Dam, Balls Ferry, and Red Bluff, the USEPA's 7DADM threshold value of 61°F was used (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51). Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-94 through 5.D-96.

At Keswick Dam and Balls Ferry, there would be no months or water year types in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-94 and Table 5.D-95). Also at Balls Ferry, there would be a 10 percent reduction under the PA in the percent of days above the threshold in September of critical water years and a concurrent increase in average daily exceedance above the threshold of 0.7°F.

At Red Bluff, the percent of days exceeding the 61°F 7DADM threshold for adult holding habitat under the PA would be more than 5 percent higher than under the NAA during July (6.5 percent) of critical water years, August of below normal water years (9.4 percent), and September of above normal (7.7 percent), below normal (10.3 percent) and critical (5.5 percent) water years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-96). There would also be reductions in the percent of days exceeding the threshold in June of critical years (5.8 percent) and August of dry (6.1 percent) and critical (6.5 percent) water years. However, in none of these situations would there also be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect on adult spring-run Chinook salmon holding.

Overall, the thresholds analysis indicates that there would be more exceedances (5 percent or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on holding adults, although this does not consider real-time operational management described in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process, that would be used to avoid and minimize any modeled effects. In addition, this analysis does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, Annual/Seasonal Temperature Management Upstream of the Delta, to improve winter-run Chinook salmon egg-to-fry survival. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. Although the process targets winter-run Chinook salmon, these changes are expected to benefit other races of Chinook salmon. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, Summary of Upstream Effects, below.

2.5.1.2.1.3 Steelhead Exposure and Risk

Sacramento River

Steelhead depend on suitable water temperatures for spawning and essentially all life functions. Like Chinook salmon in California, steelhead in California are at the southern end of their range within North America. Additionally, the majority of historical habitat in the Central Valley that provided suitable areas for spawning, egg incubation, and early life stages are now blocked by dams. Salmonids in the Sacramento River are now dependent on cold water temperature management in the upper Sacramento River (below Keswick Dam) and below Nimbus Dam on the lower American River, relying on cold water releases for their viability. The preferred water temperature for adult steelhead migration is 46°F to 52°F (McEwan and Jackson 1996; Myrick 1998; and Myrick and Cech 2000). Thermal stress may occur at temperatures beginning at 66° F and mortality has been demonstrated at temperatures beginning at 70°F. The preferred water temperature for steelhead spawning is 39°F to 52°F, and the preferred water temperature for steelhead egg incubation is 48°F to 52°F (McEwan and Jackson 1996; Myrick 1998; and Myrick and Cech 2000). The United States Environmental Protection Agency (USEPA) issued temperature recommendations for salmon and trout (USEPA 2003). The USEPA recommends a water temperature range of 39.2°F to 53.6°F for good survival of eggs during incubation studies, with an optimal range of 42.8°F to 50°F. Preferred rearing temperatures for juvenile steelhead in field and lab studies are 50°F to 62.6°F (constant temperature) or less than 64.4°F 7DADM. Optimal growth with limited food supply in lab studies was achieved at temperatures of 50 °F to 61 °F.

Steelhead may spend from one to three years (typically two) rearing in freshwater before emigrating to the marine environment as smolts (Moyle 2002). The larger juvenile life-stages are less sensitive to temperature then the alevins and yolk-sac fry but will suffer lethal and sub-lethal effects when not in optimal instream temperatures. USEPA guidelines recommend summer water temperatures do not exceed 61°F (16°C) 7DADM for juvenile rearing salmonids in the upper basin of natal rivers and not to exceed 64°F (18°C) in the lower basin of natal rivers (U.S. Environmental Protection Agency 2003). Potential sub-lethal temperature effects on juvenile salmonids include slowed growth, delayed smoltification, desmoltification, and extreme physiological changes which can lead to disease and increased predation.

Spawning, egg incubation, and alevins

Steelhead may spawn from Keswick Dam downstream to the vicinity of Red Bluff, based on the spawning distribution of Fall-run Chinook salmon. Identification of steelhead redds is complicated due to the similarity of redds formed by resident rainbow trout and those formed by co-occurring steelhead. CCV steelhead spawning and eggs/alevin incubation occurs from November through April, and water temperatures were modeled for this period from Keswick Dam downstream to Red Bluff.

In the BA, riverine water temperatures under each operational scenario, PA and NAA, were modeled and the results contrasted to each other in a comparative analysis for each location of interest, and by month and water year type. This comparative analysis noted the frequency and magnitude of differences between the two operational scenarios. Modeled mean monthly water temperatures during the November through April spawning and egg/alevins incubation period for steelhead in the Sacramento River reach of Keswick Dam to Red Bluff are presented in in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately one percent) throughout the reach in all months and water year types of the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4 percent, and would occur at Bend Bridge and Red Bluff in critical water years during February. Despite the increase, water temperatures would remain less than 52°F in both locations under both scenarios during this time, which is below the temperature range of concern for spawning and egg/alevin incubation (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. For critical years during February at Bend Bridge and Red Bluff, where the largest increase in mean monthly water temperature was seen, curves would be nearly identical between the NAA and PAA, except for 2 years in which the PA would be approximately 1°F higher (Figure 5.4 208, Figure 5.4 209). However, water temperatures would not differ in the large majority of years at both locations. These results suggest that the differences in water temperature between NAA and PA in February of critical water years would be very similar at both locations.

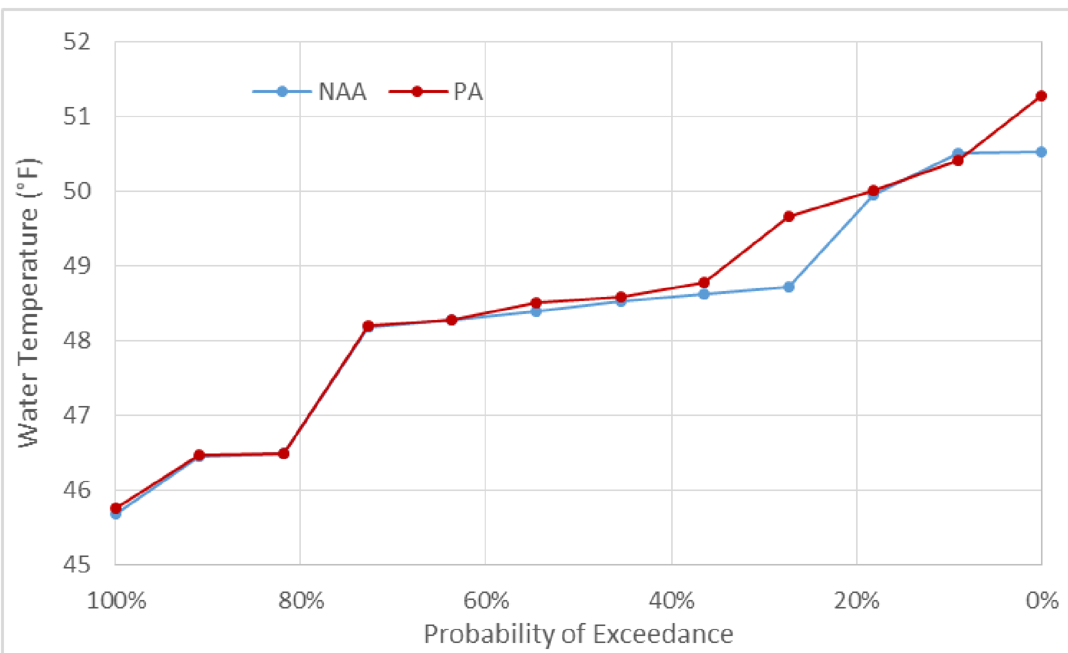

*Figure **Error! No text of specified style in document.**-5. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in February of Critical Water Years.*

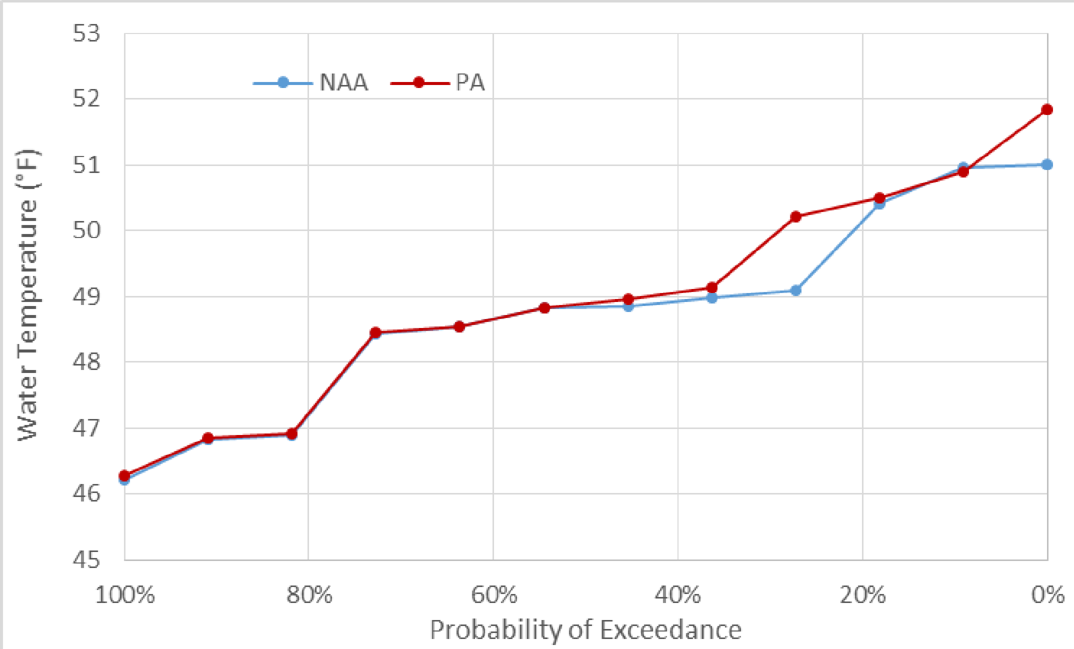

Figure ***Error! No text of specified style in document.****-6. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in February of Critical Water Years*

The exceedance of temperature thresholds in the Sacramento River presented in the BA in Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49 by modeled daily water temperatures was evaluated based on thresholds identified from the literature. For steelhead spawning and egg/alevin incubation, the thresholds used were 53°F (McCullough et al. 2001) and 56°F (McEwan and Jackson 1996) (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-97 through Table 5.D-106. At Keswick Dam, for both temperature thresholds, the modeled daily temperatures have very little difference between the PA and NAA scenarios. There would be no months or water year types in which the modeling results showed 5 percent more days under the PA scenario compared to the NAA scenario in which daily temperatures would exceed the threshold in a given month or water year type (BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-97, Table 5.D-98). There would be one instance in which the percent of days exceeding the 53°F threshold would be lower under the PA relative to the NAA: November of above normal years (8.3 percent reduction). There would be two instances in which the percent of days exceeding the 56°F threshold would be lower under the PA relative to the NAA: November of above normal (6.7 percent reduction) and below normal (5.8 percent reduction) years. However, in no case would there be a more-than-0.5°F difference in the magnitude of average daily exceedance between the PA and NAA values.

At Clear Creek, for both temperature thresholds, there would be no months or water year types in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature

Threshold Analysis Results, Table 5.D-99, Table 5.D-100). There would be 1 month and water year type, November of above normal water years, during which the percent exceedance would be lower under the PA relative to the NAA by 6.9 percent and 5.8 percent for the 53°F and 56°F thresholds, respectively. However, there would be no concurrent increase in magnitude of average daily exceedance that is more than 0.5°F for either instance.

At Balls Ferry, for both temperature thresholds, there would be no months or water year types in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-101, Table 5.D-102). There would be one water year type during November for each threshold during which the percent exceedance would be lower under the PA relative to the NAA by (53°F threshold: above normal water years, 11.7 percent lower under PA; 56°F threshold: below normal water years, 5.2 percent lower under PA). In addition, there would be no increase in magnitude of average daily exceedance that is more than 0.5°F for either instance.

At Bend Bridge, for both temperature thresholds, there would be no months or water year types in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-103, Table 5.D-104). For the 53°F threshold, there would be two instances, November of wet (8.8 percent reduction) and above normal (16.1 percent reduction) water years, in which there would be a reduction in the percent exceedance above the threshold under the PA relative to the NAA. However, there would be no concurrent increase in magnitude of average daily exceedance that is more than 0.5°F for either instance.

At Red Bluff, for both temperature thresholds, there would be no months or water year types in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-105, Table 5.D-106). For the 53°F threshold, there would be three instances, November of wet (8.3 percent reduction) and above normal (15.6 percent reduction) water years and March of below normal water years (6.7 percent reduction), in which there would be a reduction in the percent exceedance above the threshold under the PA relative to the NAA. However, there would be no concurrent increase in magnitude of average daily exceedance that is more than 0.5°F for any of these three instances.

The water temperature exceedance plots are useful for assessing whether the PA is expected to make conditions warmer, colder, or have little impact relative to the NAA. The plots clearly show that the latter (little impact) is the case. What the plots do not show is how fish life stages, in this case CCV Steelhead eggs and alevins, will be affected by the thermal regimes present under both the PA and NAA scenarios. Based on Tables 5.D-97 through 5.D-106 in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, typically more than 90 percent of the days in November are above the 53ºF threshold for egg/alevin incubation for both the Keswick and Clear Creek modeling locations on the Sacramento River. When the more lenient threshold of 56ºF is used, the percentage of days above the threshold drops to approximately 20 percent to 25 percent for the Keswick and Clear

Creek locations. These modeling results would indicate that although there is little difference in the number of water temperature exceedances between the PA and NAA scenarios, the actual water temperature conditions in the river are deleterious to spawning and egg/alevin incubation. The same trend in the results are seen for the month of December, where the average number of days above the 53°F threshold at both the Keswick and Clear Creek locations is approximately 21 percent, while the more lenient threshold of 56°F averages less than one percent. By January, water temperatures have substantially dropped and the number of days above the 53°F threshold is typically less than one percent. Typically the PA does slightly better in wetter water year types and slightly worse in drier water year types in providing suitable water temperatures for egg incubation and alevin development. However, given the high number of days in November above the 53°F thermal threshold (approximately 90 percent), most of the eggs laid in November will perish or have low viability under either operational scenario. Similarly, eggs laid in December will have approximately 20 percent to 30 percent of the days exceeding this threshold and thus, an equivalent percentile of eggs laid during this month and surviving eggs from the previous month can be assumed to be lost or have reduced fitness due to excessive temperature conditions.

The trend in water temperature exceeding the two thresholds at sites located downstream of the Clear Creek confluence (Balls Ferry, Bend Bridge, and Red Bluff) shows that water is generally cooler, and there are fewer days in November and December exceeding the thresholds. However, those locations that are farther downstream warm up faster in the spring, and have more days exceeding the two thresholds in March and April, than the Keswick and Clear Creek locations based upon the modeling. The modeling data suggests that steelhead eggs laid in November in the upper Sacramento River below Keswick Dam are at a much higher risk of mortality or developmental abnormalities due to warmer thermal conditions than eggs laid farther downstream. Conversely, eggs laid in the downstream locations (Balls Ferry, Bend Bridge, and Red Bluff) after January are at a higher risk of mortality due to the accelerated warming of the river in March and April compared to the upstream locations. Water temperatures in November and December should be considered at least a high level stressor for early spawning steelhead in the upper Sacramento River below Keswick Dam. Eggs laid in the more downstream reaches are at risk in March and April. NMFS finds that while the two scenarios are essentially equivalent in their effects on water temperature throughout the Keswick to Red Bluff river reaches, that both the PA and NAA operations during November and December, and later in March And April, will adversely affect incubating steelhead eggs and developing steelhead alevins in the gravel during November and December at the Keswick and Clear Creek locations and during March and April farther downstream from Balls Ferry to Red Bluff based on modeling information.

Kelt Emigration

Mean monthly water temperatures during the February through May kelt emigration period for steelhead in the Sacramento River upstream of the Delta are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10[2]. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately one percent) throughout the kelt emigration reach of Keswick Dam to Knights Landing in all months and water year types in the period. The largest increase in mean monthly

[2] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

water temperatures under the PA relative to NAA would be 1.0°F (1.4 percent), and would occur at Knights Landing in below normal water years during August. However this is outside the anticipated window when kelts are believed to be emigrating back down stream (February through May) and should not affect them.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the kelt emigration period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.10-7[3]). The curves for PA generally match those of the NAA. At Knights Landing in below normal water years during August, where the largest increase in mean monthly water temperature was seen, the difference between PA and NAA would be larger at the lower end of the temperatures range by nearly 2°F in 2 of the 11 years. As mentioned above, however, this is outside the temporal window that is anticipated for kelt emigration.

There have been no known studies evaluating specific temperature effects on emigrating kelts. Therefore, adult immigration thresholds of 68°F 7DADM and 70°F were used for kelt emigration thresholds, with an assumption that kelts emigrating downstream would be affected by water temperatures similarly to adults immigrating upstream (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49). The 68°F 7DADM threshold was taken from USEPA (2003) and the 70°F threshold represents the average of the studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range. The 7DADM threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-107 through Table 5.D-112. At all three locations, Keswick Dam, Bend Bridge, and Red Bluff, there would be no months or water year types with both a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance. This means that the modeling data does not show that in any given month in any one of the water year types modeled, that both a 5 percent difference between the exceedance percentiles in the PA and NAA scenarios exists concurrently with a difference in water temperature of more than 0.5°F.

When examining the percentage of days in which water temperatures exceeded the thresholds of 68°F 7DADM or 70°F during the February through May period for kelt emigration, the modeling results show that water temperatures never exceeded the thresholds at Keswick, Bend Bridge, or Red Bluff. Therefore, water temperatures should not affect kelt emigration downstream during the February through May time period. NMFS finds that the environmental conditions as portrayed by riverine water temperatures associated with the PA and NAA operations scenarios will not adversely affect kelt migration downstream during the February through May period.

Juvenile Rearing

Modeled mean monthly water temperatures during the year-round juvenile rearing period for steelhead in the Sacramento River between Keswick Dam and Red Bluff are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream*

[3] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) throughout the juvenile rearing reach in all months and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, or up to 1.1 percent, and would occur at Red Bluff in above normal years during August and above- and below normal years during September, and at Bend Bridge in below normal years during September.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the juvenile rearing period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of August (Figure 5.4 59) and September (Figure 5.4 60) during above normal years at Red Bluff, September of below normal years at Red Bluff (Figure 5.4 61), and September during below normal years at Bend Bridge (Figure 5.4 62), where the largest increases in mean monthly water temperatures were seen, reveals that there is a general trend towards marginally higher temperatures under the PA but that the difference of 0.6°F in mean monthly temperatures between NAA and PA, the largest throughout the juvenile rearing period, would cause little change to the curves.

Water temperature thresholds of 63°F mean monthly and 69°F (7DADM) were used to evaluate water temperature threshold exceedances during the steelhead juvenile rearing life stage in the Sacramento River between Keswick Dam and Red Bluff (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49). The 63°F threshold was derived by taking the intermediate value of the ranges of optimal growth from several studies (Grabowski 1973; Wurtsbaugh and Davis 1977; Hokanson et al 1977; Myrick and Cech 2005; and Beakes et al. 2014). The 69°F 7DADM used was based on Sullivan (2000) and was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in the BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-113 through 5.D-122. At Keswick Dam, for both thresholds, there would be no months or water year types in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-113, Table 5.D-114). This means that the modeling data does not show that in any given month in any one of the water year types modeled, that both a 5 percent difference between the exceedance percentiles in the PA and NAA scenarios exists concurrently with a difference in water temperature of more than 0.5ºF. There would be 1 month and water year type in which the percent of days exceeding the threshold would be 7.8 percent lower under the PA relative to the NAA, but the magnitude of average daily exceedance above the threshold would be 0.9°F higher under the PA. From January through July, there are no days in which the 63ºF threshold is exceeded in either the PA or NAA scenarios. Starting in August, and continuing through October, the 63°F mean monthly threshold is exceeded for both the PA and NAA scenarios. The percentage of days exceeding the threshold is higher for the PA in August, but not in September and October. These exceedances occur in critical years, and can reach approximately 50 percent of the days in September, and 25 percent of the days in October. The degrees per day above the threshold tend to be higher for the PA in August and September, but not for October. This information from the modeling suggests that water temperature levels in August, September, and October may reach levels that adversely impact steelhead juvenile rearing in the Keswick reach and would negatively impact their viability. If the 7DADM of 69ºF is used as the threshold, there are no exceedances during these same summer months and thus the data suggests that there would be no discernable effect based on the threshold temperature criteria.

At Clear Creek, for both thresholds, there would be no months or water year types in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-115, Table 5.D-116). This means that the modeling data does not show that in any given month in any one of the water year types modeled, that both a 5 percent difference between the exceedance percentiles in the PA and NAA scenarios exists concurrently with a difference in water temperature of more than 0.5ºF. There would be one instance in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the 69°F threshold (September of critical water years, 5.3 percent increase), and two instances in which there would be a more-than-0.5°F increase in the magnitude of average daily exceedance above the 63°F threshold (September of critical years and all water year types combined, 0.6°F for both), but no instances would have both conditions met concurrently. Starting in August, and continuing through October, the 63°F mean monthly threshold is exceeded for both the PA and NAA scenarios in critical water year types. The percentage of days exceeding the threshold is higher for the PA in August (22.3 versus 21.8 percent), but not in September and October. These exceedances occur in critical years, and can reach approximately 60 percent of the days in September, and 29 percent of the days in October. The degrees per day above the threshold tend to be higher for the PA in August and September, but not for October. This information from the modeling suggests that water temperature levels in August, September, and October of critical years may reach levels that adversely impact steelhead juvenile rearing in the Clear Creek reach and would negatively impact their viability. If the 7DADM of 69ºF is used as the threshold, the threshold is exceeded during September of critical water year types for both the PA and NAA, with the PA having a greater percentage of days above the threshold (15.0 percent versus 9.7 percent). However the degrees per day exceedance is slightly lower for the PA than the NAA modeled scenario (0.74 versus 0.77). The data suggests that there would be adverse effects due to temperature during the August through October temporal period at the Clear Creek location during critical water year types for rearing juvenile steelhead based on the threshold temperature criteria.

At Balls Ferry, for both thresholds, with one exception, there would be no months or water year types in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-117, Table 5.D-118). The one exception would occur under the 69°F 7DADM threshold in September of critical water years (6.7 percent increase). However, there would not be a concurrent increase of more-than-0.5°F difference in the magnitude of average daily exceedance. Starting in August, and continuing through October, the 63°F mean monthly threshold is exceeded for both the PA and NAA scenarios in critical water year types. The percentage of days exceeding the threshold is higher for the NAA in August (31.7 5 versus 28.5 percent), September (64.2 versus 61.9 percent) and October (31.5 percent versus 30.6 percent). These exceedances occur only in critical water years. The degrees per day above the threshold tend to be higher for the PA in August and September, but not for October. This information from the modeling suggests that water temperature levels in August, September, and October of critical water year types may reach levels that adversely impact steelhead juvenile rearing in the Balls Ferry reach and would negatively impact their viability under both scenarios. If the 7DADM of 69°F is used as the threshold, the threshold is exceeded during August and September of critical water year types for both the PA and NAA, with the PA having a greater percentage of days above the threshold (3.5 percent versus 1.6 percent in August, and 21.1 percent versus 14.4 percent in September). However, the degrees per day exceedance is lower for the PA than the NAA modeled scenario (0.46 versus 0.67 in August) and equal in September (1.12). The data suggests that there would be adverse effects due to temperature during the August through September temporal period at the Balls Ferry location during critical water year types for rearing juvenile steelhead based on the threshold temperature criteria.

At Bend Bridge, for both temperature thresholds, there would be no months or water year types in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-119, Table 5.D-120). There would be one instance for the 63°F threshold in which the percent of days exceeding the threshold would be lower under the PA relative to the NAA, September of critical water years (6.4 percent reduction), but there would be a 0.5°F increase in the magnitude of average daily exceedance. Starting in July, and continuing through October, the 63°F mean monthly threshold is exceeded for both the PA and NAA scenarios. The percentage of days exceeding the threshold is higher for the PA in July (3.8 percent versus 2.7 percent, critical years) and September (2.1 percent versus 0.9 percent, below normal years), and higher for the NAA in August (0.2 percent versus 0.0 percent, dry years; 39.0 percent versus 38.7 percent, critical years), September (7.8 percent versus 6.5 percent dry years; 74.2 percent versus 67.8 percent, critical years) and October (31.7 percent versus 29.6 percent, critical years). The degrees per day above the threshold tend to be higher for the PA in August and September, but not for October. This information from the modeling suggests that water temperature levels in August, September, and October may reach levels that demonstrably impact steelhead juvenile rearing in the Bend Bridge reach and would negatively impact their viability under both scenarios in drier water year types. If the 7DADM of 69°F is used as the threshold, the threshold is exceeded during August, September , and October for both the PA and NAA, with the PA having a greater percentage of days above the threshold (7.5 percent versus 6.5 percent in August, and 22.5 percent versus 18.1 percent in September, both in critical years). The NAA has a slightly higher percentage of exceedance days in October (1.1 percent versus 0.8 percent, in critical years). The degrees per day exceedance is higher for the PA than the NAA modeled scenario in August (1.39 versus 1.13), September (1.28 versus 1.26) and October (0.33 versus 0.25), all in critical years. The data suggests that there would be adverse effects due to temperature during the August through October temporal period at the Bend Bridge location for rearing juvenile steelhead in drier water year types based on the threshold temperature criteria.

At Red Bluff for both thresholds, with one exception, there would be no months or water year types in which there would be both 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-121, Table 5.D-122). The one exception would occur under the 69°F 7DADM threshold in September of critical water years (9.4 percent increase in frequency of exceedance). However, there would not be a concurrent more-than-0.5°F difference in the magnitude of average daily exceedance. Starting in May, and continuing through October, the 63°F mean monthly threshold is exceeded for both the PA and NAA scenarios. The percentage of days exceeding the threshold is higher for the PA in June (1.0 percent versus 0.9 percent, wet years), July (19.4 percent versus 15.1 percent, critical years), August (0.5 percent versus 0.4 percent wet years, and 45.7 versus 43.8 percent in critical years) and September (12.4 percent versus7.6 percent, below normal years and 28.0 percent versus 24.0 percent in dry years). The percentage of days which exceed the 63ºF threshold is higher for the NAA scenario in May (1.9 percent versus 1.6 percent in dry years, 1.9 versus 1.1 in critical years), June (3.9 percent versus 1.9 percent, critical years), August (6.3 percent versus 2.1 percent, dry years), September (85.8 percent versus 81.9 percent, critical years), and October (35.8 percent versus 34.4 percent, critical years). The degrees per day above the threshold present mixed results, with some months and water years higher for the PA, and in other combinations, the PA is lower than the NAA scenario. This information from the modeling suggests that water temperature levels in July, August, September, and October of critical and dry water year types may reach levels that demonstrably impact steelhead juvenile rearing in the Red Bluff reach and would negatively impact their viability under both scenarios. If the 7DADM of 69ºF is used as the threshold, the threshold is exceeded during August, September , and October for both the PA and NAA, with the PA having a greater percentage of days above the threshold (11.3 percent versus 8.3 percent in August, and 47.2 percent versus 37.8 percent in September, both in critical years). The NAA has a slightly higher percentage of exceedance days in October (5.4 percent versus 3.0 percent, in critical years). The degrees per day exceedance is higher for the PA than the NAA modeled scenario in August (1.64 versus 1.61) and October (1.00 versus 0.95), both in critical years. The NAA has a higher level in September (1.82 versus 1.71, critical year). The data suggests that there would be adverse effects due to temperature during the August through October temporal period of critical water year types at the Red Bluff location for rearing juvenile steelhead based on the threshold temperature criteria.

Overall, NMFS finds that the environmental conditions as portrayed by riverine water temperatures associated with the PA and NAA operational scenarios will adversely affect juvenile rearing during the August through October period from Keswick Dam downstream to Red Bluff based on the modeling. In the farthest downstream reach modeled (Red Bluff), water temperatures under both the PA and NAA operational scenarios have the potential to adversely affect rearing steelhead in June and July as well.

An additional threshold analysis was conducted to determine how the PA would affect steelhead smoltification. A 54°F threshold was used and was based on an average of temperatures from Zaugg and Wagner (1973), Adams et al. (1975), Zaugg (1981), and Hoar (1988), above which smoltification can be impaired. This analysis was conducted for January through March in the reach from Keswick Dam to Red Bluff.

Results of the water temperature thresholds analysis for steelhead smoltification are presented in the BA (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-123 through Table 5.D-127). At all locations analyzed, Keswick Dam, Clear Creek, Balls Ferry, Bend Bridge, and Red Bluff, there would be no months or water year types with a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA or with a more-than-0.5°F difference in the magnitude of average daily exceedance. However, the modeling showed that in both the PA and NAA, water temperatures exceeded the 54°F threshold in January at Keswick, January and February at Clear Creek, and in March at Balls Ferry, Bend Bridge, and Red Bluff. The percent of days above the threshold was less than 10 percent at all locations, except Red Bluff. At this location, the percentage of days ranged up to 18.0 percent (NDD) in March of critical years and was above approximately 10 percent for both the PA and NAA scenarios in below normal and dry year types. NMFS finds that there will be adverse effects to the smoltification process for steelhead juveniles. Impairment of the smoltification process will occur in January in the Keswick reach, January and February in the Clear Creek reach, and March in the Red Bluff reach due to the effects of operations under the PA and NAA, as modeled.

Smolt Emigration

Modeled mean monthly water temperatures in the Sacramento River in the reach from Keswick Dam to Red Bluff during the November through June smolt emigration period, with a peak during January through March are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) throughout the Sacramento River upstream of the Delta in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.3°F (0.5 to 0.7 percent), and would occur at Keswick Dam, above Clear Creek, Balls Ferry, and Bend Bridge in below normal years during May, which is outside the peak period of smolt emigration but within the limits of the entire emigration season. Despite this increase, temperatures would be in the low- to mid-50s range (°F) under both scenarios, which is well below temperatures of concern (64°F 7DADM) for smolt emigration.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the smolt emigration period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of below normal years during May at Keswick Dam (Figure Error**! No text of specified style in document.**-7), above Clear Creek (BA Figure, not presented here), Balls Ferry (BA Figure, not presented here), and Bend Bridge (Figure Error**! No text of specified style in document.**-8), where the largest increases in mean monthly water temperatures were seen, reveals that the curves were similar overall. The 0.3°F increase under the PA is the result of 1 year at Keswick Dam, above Clear Creek, and Balls Ferry, and the result of two years at Bend Bridge. Further examination of these months and years reveals that this appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs. There are no operational requirements, such as cold-water pool storage, temperature, or outflow requirements, that would cause these years to differ so widely in water temperatures. Therefore, there is no practical reason why real operations under the PA would be different from those under the NAA in these months and years.

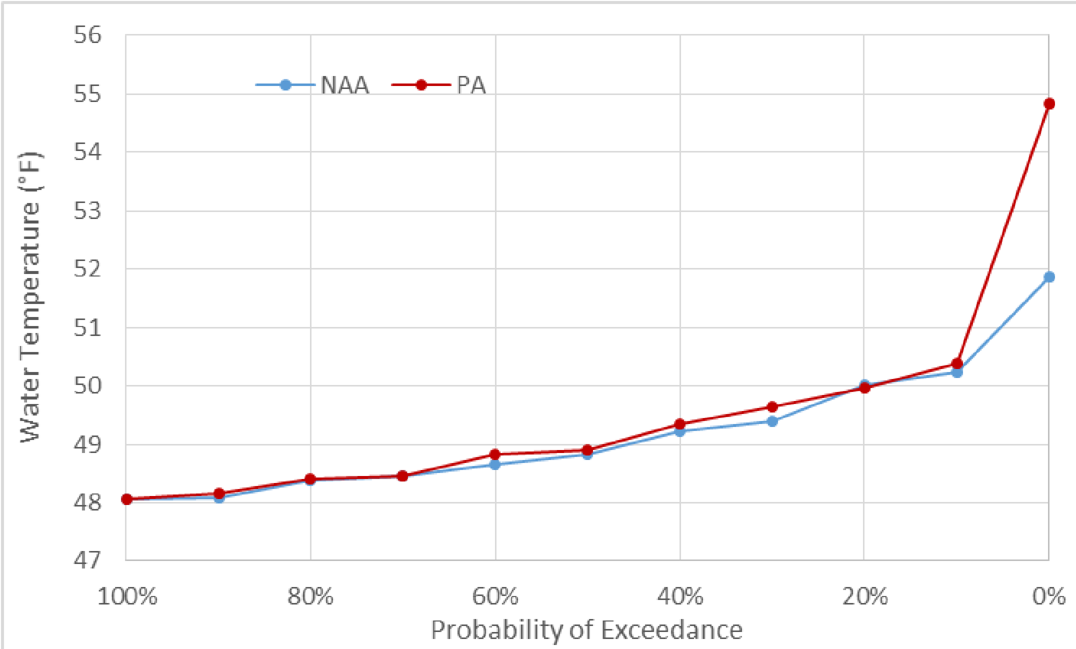

*Figure **Error! No text of specified style in document.**-7. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Keswick Dam in May of Below Normal Water Years*

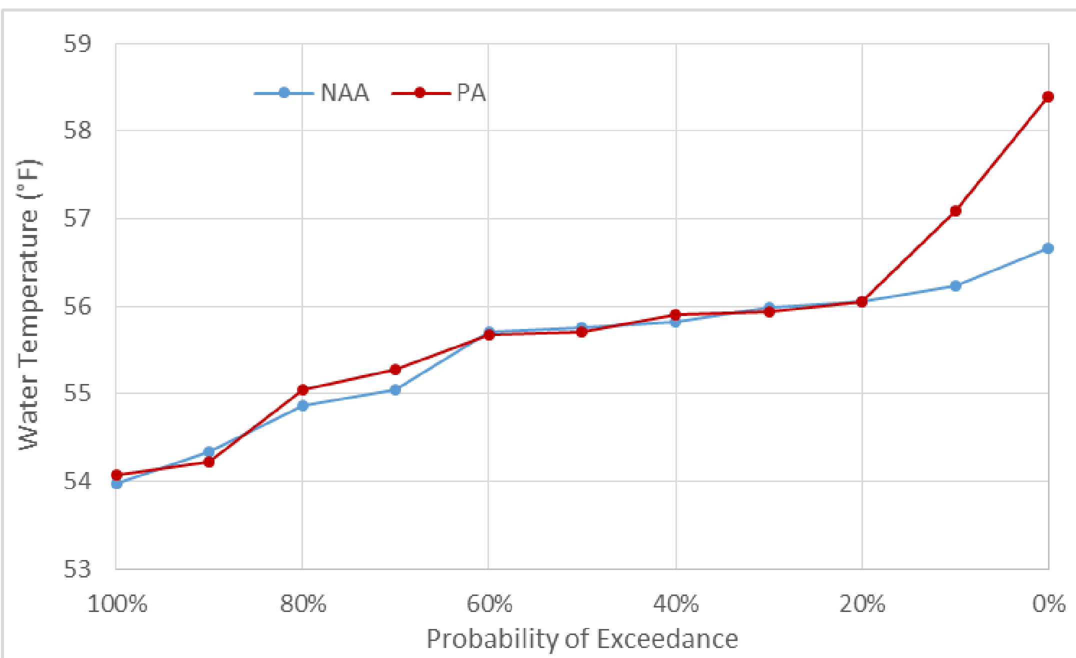

*Figure **Error! No text of specified style in document.**-8. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in May of Below Normal Water Years*

The exceedance of temperature thresholds in the Sacramento River presented in the BA in Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49 by modeled daily water temperatures were evaluated based on thresholds identified in the USEPA's temperature water quality guidance (U.S. Environmental Protection Agency 2003). Two thresholds, 61°F 7DADM and 64°F 7DADM, were evaluated. The 61°F value corresponds to the upper end of the optimal smolt emigration range and represents each site as a core habitat location, and the 64°F value corresponds to the upper end of the suboptimal range and represents each site as a non-core habitat location. The 7DADM values were converted by month to function with daily model outputs (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51). Both thresholds were evaluated from Keswick Dam to Red Bluff.

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-128 through Table 5.D-137. At Keswick Dam, Clear Creek, Balls Ferry, Bend Bridge, and Red Bluff, there would be very few exceedances above either threshold. At all locations for both thresholds, there would be no months or water year types with both a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance. Based on the modeling, there are no exceedances for either the 61^{o}F 7DADM or 64^{o}F 7DADM thresholds in the Keswick reach for either the PA or NAA scenario. At the Clear Creek location, the modeling indicates that exceedances occur in November, which is outside of the peak emigration period (January through March; but within the period of observed smolt emigration, November through June). At the Balls Ferry location, exceedances occur in November, May, and June, which are outside of the peak emigration period. All of the exceedances are less than 5 percent of the potential days within the month. At Bend Bridge and Red Bluff, exceedances are more frequent and occur in November, April, May, and June, with the percentage of days approaching 50 percent in critical years at Red Bluff in June. However, all of these months are outside the peak emigration period. Overall, the modeling data suggests that the emigration of steelhead smolts will be minimally affected by water temperatures exceeding the EPA thresholds of 61^{o}F 7DADM or 64^{o}F 7DADM for core and non-core areas, respectively.

NMFS finds that the temperature exceedances as represented by the modeling will not adversely affect smolt emigration during the peak period of steelhead migration downstream (January through March). Adverse effects are likely to occur outside of the peak emigration period, particularly in downstream locations in April, May, and June.

Adult immigration

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Bend Bridge, and Red Bluff during the August through March adult immigration period for steelhead are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-7, Table 5.C.7-8. Overall, mean water temperatures would change very little (predominantly less than 1°F, or approximately one percent) due to the PA at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, or up to 1.1 percent, and would occur at Red Bluff in above normal years during August and above- and below normal years during September, and at Bend

Bridge in below normal years during September. These increases during September would overlap with the period of peak adult immigration (September through November).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult immigration period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of above normal water years during August at Red Bluff (Figure Error**! No text of specified style in document.**-1), above normal Figure Error**! No text of specified style in document.**-2) and below normal (Figure **Error! No text of specified style in document.**-3) water years during September at Red Bluff, and below normal water years during September at Bend Bridge (Figure Error**! No text of specified style in document.**-4), where the biggest water temperature increases of 0.6°F were seen, reveals that there is a general trend towards slightly higher temperatures under the PA but that the difference in mean monthly temperatures between NAA and PA has little effect on the differences in values presented in the exceedance plots.

To evaluate water temperature threshold exceedance during the adult immigration life stage at Keswick Dam, Bend Bridge, and Red Bluff, the USEPA's 7DADM threshold value of 68°F (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49) was used. The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51). In addition, the mean monthly threshold of 70°F, the average of studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range, was used.

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results,* Table 5.D-138 through Table 5.D-143. At Keswick Dam and Red Bluff, for both thresholds there would be no months or water year types with either a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA or a more-than-0.5°F difference in the magnitude of average daily exceedance.

At Bend Bridge, the percent of days exceeding the 68°F 7DADM threshold under the PA would be more than 5 percent higher than under the NAA during August (5.1 percent) and September (5.3 percent) of critical water years (BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results,* Table 5.D-140 and Table 5.D-141). However, in no month or water year type would there be a more-than-0.5°F difference between NAA and PA in the magnitude of average daily exceedance above the threshold. Furthermore, there would be no months or water year types with either a more-than-5 percent increase in the percent of total days exceeding the 70°F threshold under the PA relative to the NAA or a more-than-0.5°F difference in the magnitude of average daily exceedance. The percentage of days in which the water temperature exceeded the 68°F 7DADM threshold is 11.6 percent for the NAA and 16.7 percent for the PA in August, and 28.1 percent for the NAA and 33.3 percent for the PA in September. At the same location, the percentage of days in which the water temperature exceeded the 70°F threshold is 3.3 percent for the NAA and 4.7 percent for the PA in September.

At Red Bluff, the percentage of days in which the water temperature exceeds the 68°F 7DADM threshold exceeds 20 percent in August and 50 percent in September in both the PA and NAA scenarios, with the PA having up to 4 percent more days in September. These exceedances occur in critical water year types. When the higher 70°F mean monthly threshold is used, exceedances still occur in August and September in critical years, but the percentage of days in which exceedances occur falls to approximately 5 percent in August and 10 percent in September.

Overall, the thresholds analysis indicates that there would be more exceedances (five percent or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on immigrating adults. These exceedances would occur early in the immigration season (August and September) in the upper river. This time period overlaps with the beginning of the peak season of adult CCV steelhead immigration during September and October and has the potential to adversely affect adult steelhead physiologically during this period. Potential effects include diminishment of egg viability prior to spawning, leading to embryo morbidity during incubation, and mortality post hatching due to malformations incompatible with viability, thus reducing the potential magnitude of the next generation's population. NMFS finds that the elevated water temperatures under both the PA and NAA operating scenarios during September and August of critical years will adversely affect the fitness of immigrating adult steelhead moving through the upper Sacramento River between Red Bluff and Keswick.

Adult holding

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Balls Ferry, and Red Bluff during the September through November CCV steelhead adult holding period are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-5, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, or up to 1.1 percent, and would occur at Red Bluff in above- and below normal years during September.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult holding period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.5-7, Figure 5.C.7.8-7). The curves for PA generally match those of the NAA. Further examination of above normal (

Figure Error**! No text of specified style in document.**-2 and below normal (Figure Error**! No text of specified style in document.**-3) years during September at Red Bluff, the month and water year types with the largest changes in water temperatures (0.6°F), reveals that there is a general trend towards marginally higher temperatures under the PA but that the difference of 0.6°F in mean monthly temperatures between NAA and PA would cause no demonstrable differences between curves for the NAA and PA in each exceedance plot.

To evaluate water temperature threshold exceedance during the steelhead adult holding life stage at Keswick Dam, Balls Ferry, and Red Bluff, the USEPA's 7DADM threshold value of 61°F was used as presented in the BA (Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-144 through 5.D-146. At Keswick Dam, there would be no months or water year types with both a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-144). The percentage of days above the 61º 7DAMD threshold at Keswick is approximately 32 percent during August of critical years, 62 percent in September of critical years, and 50 percent in October of critical years for both scenarios. The modeling indicates that there is substantial potential for exceedances of the threshold for optimal water temperatures required for the holding of adult steelhead below Keswick Dam.

At Balls Ferry, there would be no months or water year types with a more-than-5 percent increase in the percent of total days exceeding either threshold under the PA relative to the NAA (BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-145). However, there would be two more-than-five-percent reductions under the PA relative to the NAA in the percent of total days exceeding the 61°F 7DADM threshold: September (10 percent lower) and October (14 percent lower) of critical water years. During October of critical years, the difference in average daily exceedance above the threshold between the PA and NAA would be less than 0.5°F. In September, the average daily exceedance above the threshold under the PA would be 0.7°F higher than that under the NAA, indicating that the frequency of days above the threshold would decrease under the PA, but exceedances would be higher on average. The percentage of days above the 61º 7DAMD threshold at Balls Ferry is approximately 45 percent during August of critical years, 11 percent in dry and 85 percent in critical years in September, 69 percent in October of critical years, and 4 percent in November of critical years for both scenarios, with the NAA scenario typically having greater probability of exceedances than the PA scenario. The modeling indicates that there is substantial potential for exceedances of the threshold for optimal water temperatures required for the holding of adult steelhead.

At Red Bluff for both thresholds, there would be no months or water year types with both a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-146). There would be some instances when there would be a more-than-5 percent increase in the percent of total days exceeding the 61°F 7DADM threshold under the PA relative to the NAA, including August of below normal water years (9.4 percent increase) and September of above normal (7.7 percent increase), below normal (10.3 percent increase), and dry (5.5 percent increase) water years, but under the PA, none of these would see a concurrent increase of at least 0.5°F in the magnitude of average daily exceedance above the threshold. The percentage of days above the 61º 7DAMD threshold at Red Bluff increases from August through September, with a gradual decrease in October. In critical years, the percentage of days in which the threshold is exceeded increases from approximately 80 percent in August to greater than 97 percent in September, and is still approximately 80 percent in October. From August through October, the potential for water temperatures to exceed the 61°F 7DADM threshold exists for all water year types and indicates that conditions for holding adult steelhead is degraded under both the PA and NAA scenarios at the Red Bluff location.

NMFS finds that the elevated water temperatures under both the PA and NAA operating scenarios from August through October will adversely affect the fitness of holding adult in the upper Sacramento River between Red Bluff and Keswick.

American River

Spawning, Eggs Incubation and Alevin

Modeled mean monthly water temperatures during the December through May spawning and egg incubation/alevins period for steelhead in the American River reach between Hazel Avenue and Watt Avenue are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* E, Table 5.C.7-15.

Overall, the PA would change mean water temperatures very little (less than 1°F, or less than one percent) throughout the reach in all months and water year types of the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4 percent, and would occur at Watt Avenue during critical years in March. This greatest increase would occur during the peak spawning and egg incubation/alevins period (January through March) on the American River.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results,* Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of critical water years during March at Watt Avenue, where the largest increase in mean monthly water temperature was seen, reveals that the curves were similar overall and that that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in the exceedance plot (Figure Error**! No text of specified style in document.**-9).

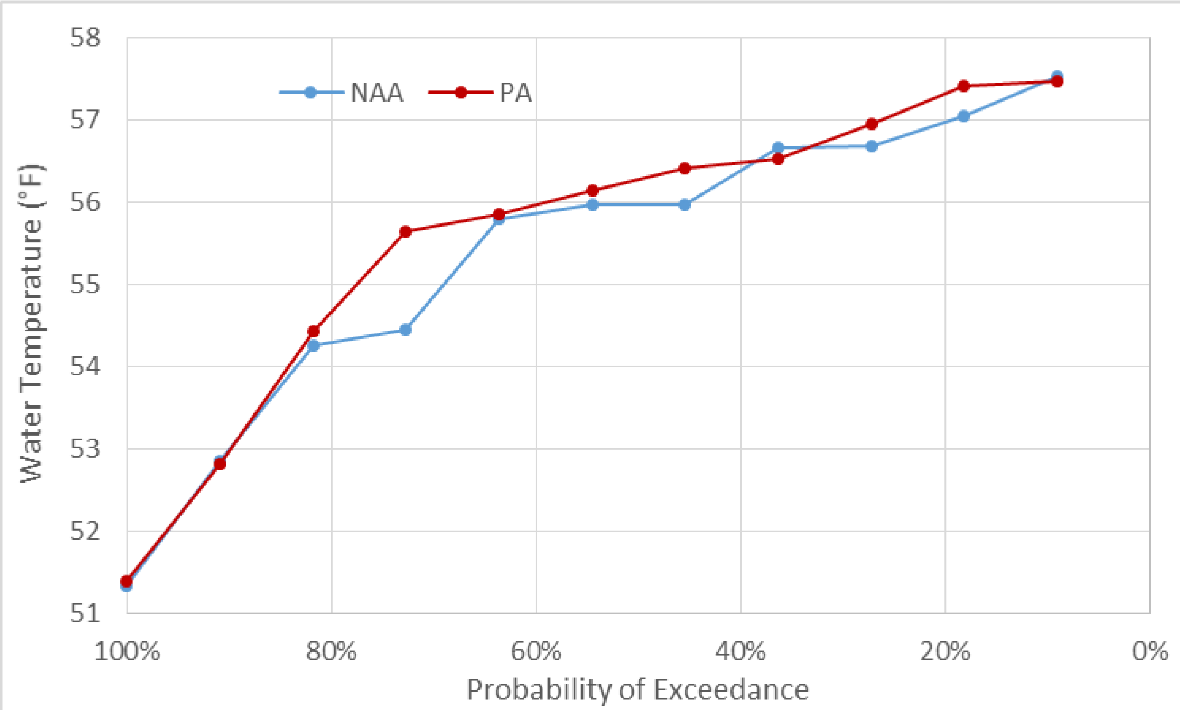

Figure ***Error! No text of specified style in document.****-9. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in March of Critical Water Years*

The exceedance of temperature thresholds in the American River presented in the BA in Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-50 by modeled daily water temperatures were evaluated based on thresholds identified from the literature. For steelhead spawning and egg/alevin incubation, the threshold used was 53°F (McCullough et al. 2001).

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-161 through Table 5.D-162. At both Hazel Avenue and Watt Avenue, there would be no months or water year types in which there would be either 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold or a more-than-0.5°F difference in the magnitude of average daily exceedance. However, examination of the modeled temperature exceedances indicate that under both the PA and NAA scenarios the water temperature threshold for optimal egg/alevin development and survival is exceeded in December, March, April, and May. In April and May, the 53°F threshold is exceeded over 70 percent of the time in April, and 100 percent of the time in May at the Hazel Avenue location. This strongly indicates that eggs that are still in the gravel or laid in April and May will have the potential for substantially reduced viability and a high proportion of mortality or embryo abnormalities which will affect their future survival and fitness. The percentage of daily exceedances increases at the Watt Avenue location, which is farther downstream than the Hazel Avenue location, during the spring months, and is relatively similar during December. Exceedances of the 53°F threshold at the Watt Avenue location start in February during dry and critical water year types (20 percent in critical years). By March, the percentage of daily exceedances is approximately six percent in wet and above normal years, 40 to 50 percent in below normal and dry years, and 83 percent in critical years. The daily percentage of exceedances above the threshold reaches 90 percent or greater in most water year types in April and May at the Watt Avenue location. This data indicates that the water temperatures will be above the optimal threshold levels for most spawning from March through May, and that eggs and alevins that are still in the gravel during this time period will have a greater potential for mortality or reduced fitness and viability.

NMFS finds that the elevated water temperatures under the PA and NAA operational scenarios will adversely affect egg incubation and alevin development at the Watt Avenue location in December and from February through June, particularly in drier water year types. Water temperatures at the Hazel Avenue location, which is the farthest upstream location accessible to steelhead in the American River and is just below Nimbus Dam, will adversely affect egg incubation and alevin development in December, and in April and May.

Kelt Emigration

Modeled mean monthly water temperatures during the February through May kelt emigration period for steelhead in the American River from Hazel Avenue to Watt Avenue are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-14, Table 5.C.7-15.

Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or less than one percent) throughout the reach in all months and water year types of the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4 percent, and would occur at Watt Avenue during critical years in March.

Exceedance plots of mean monthly water temperatures were examined during each month and water year type throughout the kelt migration period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of critical water years during March at Watt Avenue, where the largest increase in mean monthly water temperature was seen, reveals that the curves were similar overall and that that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in the exceedance plot (Figure Error**! No text of specified style in document.**-10).

There have been no known studies evaluating specific temperature effects on emigrating kelts. Therefore, adult immigration thresholds of 68°F 7DADM and 70°F were used for kelt migration, with an assumption that kelts migrating downstream would be affected by water temperatures similarly to adults migrating upstream (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-50). The 68°F 7DADM threshold was taken from (U.S. Environmental Protection Agency 2003) and the 70°F threshold represents the average of the studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range. The 7DADM threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-52).

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-163 through Table 5.D-166. At both Hazel Avenue and Watt Avenue, there would be no months or water year types with either a more-than-5 percent increase in the percent of total days exceeding the 68°F 7DADM or 70°F threshold under the PA relative to the NAA, or a more-than-0.5°F difference in the magnitude of average daily exceedance.

When examining the percentage of days in which water temperatures exceeded the thresholds of 68°F 7DADM or 70°F during the February through May for kelt emigration, the modeling found that water temperatures rarely exceeded the thresholds at Hazel Avenue for the 68ºF 7DADM and when this event occurred, it was by a minimal percentage of days (less than 3.5 percent in critical years for the PA). The 70ºF threshold was never exceeded at Hazel Avenue for the same February through May time period. At the Watt Avenue location, exceedances of the 68ºF 7DADM were more frequent and a higher percentage of days above the threshold were seen in the month of May. The modeled results for the PA indicated equivalent percentages of exceedance in the wetter year types, lower percentages of exceedances in below normal and dry water year types, but more frequent exceedances in the critical year type. In below normal and dry water year types, the modeling indicated that approximately 18 percent to 24 percent of the days in May would be above the threshold for both scenarios. This increased to 43 percent to 45 percent in critical year types. There were less frequent exceedances of the 70ºF threshold as compared to the 68ºF 7DADM. For all water year types except dry years, the percentage of exceedances were equivalent. In dry years the PA scenario had a slightly lower rate of exceedance than the NAA scenario (5.2 percent to 6.1 percent). In critical years, there was still an approximately 22 percent chance of exceeding the 70ºF threshold in May in critical years Therefore, water temperatures should not affect kelt emigration downstream during the February through April time period, but may start to affect kelts in May as water temperatures warm in the lower portions of the American River.

NMFS finds that the water temperatures, as modeled under both the PA and NAA operational scenarios, will not adversely affect kelt emigration during the February through April period, but may begin to adversely affect kelt migration during May of critical years.

Juvenile Rearing

Modeled mean monthly water temperatures during the year-round juvenile rearing period for steelhead in the American River between Hazel Avenue and Watt Avenue are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-14, Table 5.C.7-15.

Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately one percent) throughout the juvenile rearing reach in all months and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F, or up to 1.4 percent, and would occur at Watt Avenue in critical water years during August.

Exceedance plots of mean monthly water temperatures were examined during each month and water year type throughout the juvenile rearing period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of critical water years during August at Watt Avenue, where the largest increase in mean monthly water temperature was seen, reveals that the colder end of the curves overlap substantially, but the higher end of the PA curves indicate that water temperatures are up to approximately 4°F higher for individual months depending on the exceedance percentile (Figure Error**! No text of specified style in document.**-10).

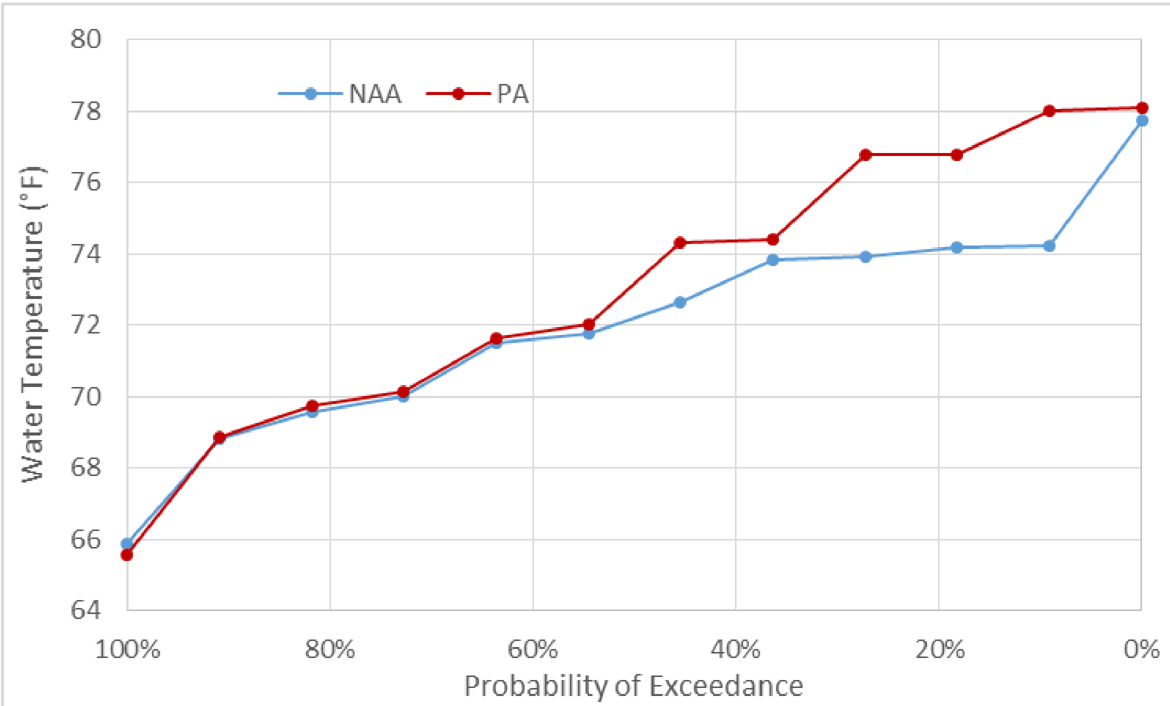

Figure ***Error! No text of specified style in document.****-10. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in August of Critical Water Years*

Thresholds water temperatures of 63°F and 69°F (7DADM) were used to evaluate water temperature threshold exceedances during the steelhead juvenile rearing life stage in the American River between Hazel Avenue and Watt Avenue (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-50). Temperature thresholds were derived according to the methods previously discussed in the Sacramento River section for juvenile rearing.

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-167 through 5.D-170. At Hazel Avenue, there would be two instances in which there would be more than 5 percent more days under the PA compared to the NAA on which temperatures would exceed the 63°F threshold: June (7.7 percent higher) and October (8.6 percent higher) of above normal water years. In neither instance would the magnitude of average daily exceedance under the PA be more than 0.5°F greater than that under the NAA. For the 69°F 7DADM threshold, there would be three instances in which there would be more than 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold: July of below normal water years (5.6 percent higher), August of critical water years (21.0 percent higher), and September of dry years (5.3 percent higher). In July of below normal years, the average daily exceedance above the threshold under the PA would also be 1.0°F higher than that under the

NAA. Furthermore, in August of critical water years, the average daily exceedance above the threshold under the PA would also be 0.7°F higher than that under the NAA. These two instances could represent biologically meaningful negative effects on rearing juvenile steelhead. In September of dry years, there would be no concurrent increase of more than 0.5°F in the magnitude of average daily exceedance under the PA relative to the NAA.

When examining the percentage of days in which the 63°F threshold is exceeded at the Hazel Avenue location, the modeling indicates that the threshold temperature will not be exceeded from December through April. By May, modeled water temperatures increase at Hazel Avenue, increasing the percentage of days that exceed the threshold, particularly in drier water year types. The percentage of days exceeding the threshold reaches almost 40 percent for both the PA and NAA in critical years. In June, exceedances are approximately 11 percent for wet years, greater than 30 percent in above normal years, and over 50 percent in below normal and dry water year types. Critical water year types are predicted to have 80 percent of the days in May exceed the threshold criteria. For the remainder of the summer through September, approximately 90 percent of the days will be above the 63°F threshold water temperature for juvenile rearing. In October, water temperatures are still elevated and the modeling predicts that at least 50 percent of the days will exceed the threshold criteria in all but wet water year types. The modeling data indicates that there is a high potential for adverse water temperature conditions at the Hazel Avenue location that will negatively affect the viability of juvenile steelhead rearing in this reach of the river based on the 63°F threshold.

When using the higher water temperature threshold of 69°F 7DADM, there are no exceedances in water temperature from January through April, and very minimal exceedances in May for both the PA and NAA modeled scenarios. Water temperatures begin to exceed the 69°F 7DADM threshold in June particularly for drier water year types. The exceedance percentage for below normal water year types is 13.6 percent for the NAA, and only 1.8 percent for the PA. In dry and critical water year types, the PA has a greater percentage of exceedances, 10.0 percent versus 9.7 percent in dry years and 17.8 percent versus 15.8 percent in critical years. Water temperatures continue to exceed the threshold temperature throughout the summer, but particularly in critical years. In July, the exceedance in a critical year is approximately 58 percent for both the PA and NAA, with the PA scenario being slightly greater. In August of critical years, the difference between the PA and NAA scenarios is much greater, 43.8 percent (PA) versus 22.8 percent (NAA). Conversely in September, the NAA scenario has a higher percentage of days exceeding the threshold in critical years 48.9 percent versus 46.1 percent, but in dry years the PA has a greater percentage of threshold exceedance days than the NAA scenario (13.8 percent versus 8.5 percent). By October, the water has cooled sufficiently that few days exceed the thermal threshold of 69°F 7DADM in any water year type, and there are no exceedances in the months of November and December for either the PA or NAA modeling scenarios. The Hazel Avenue location is the farthest upstream river reach that is currently accessible to steelhead on the American River. Any thermal threshold exceedances seen here in the modeling results would indicate that the entire American River corridor downstream of this location would also likely be over the threshold, as there are no significant tributaries downstream of this location to modify the water temperature.

At Watt Avenue, there would be no instances in which there would be more than 5 percent more days under the PA compared to the NAA on which temperatures would exceed the 63°F threshold (BA Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis*

Results, Table 5.D-169). There would be one water year type within 1 month in which the magnitude of average daily exceedance under the PA would be more than 0.5°F greater than that under the NAA: August of critical water years (1.0°F increase). There would be no instances in which there would be more than 5 percent more days under the PA compared to the NAA on which temperatures would exceed the 69°F threshold (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-170), and the magnitude of average daily exceedance would be less than 0.5°F for this instance.

The water temperature modeling for the PA and NAA shows that there are no exceedances above the 63°F threshold from January through March. By April, warming river temperatures begin to exceed the threshold. These exceedances occur in below normal, dry, and critical water year types, and the greatest percentage of exceedances occur in critical water years (approximately 31 percent of the days). In May, the percentage of days above the thermal threshold continues to increase, ranging from approximately 13.7 percent in wet years to almost 80 percent in critical years. In June, all but the wet water years (approximately 50 percent) are above 80 percent exceedance with critical years over 95 percent. From July through September nearly 100 percent of the days exceed the 63°F threshold. By October, the water temperatures are beginning to cool, and the percentage of days that exceed the thermal threshold begins to decline, but is still in the 70 to 85 percent range for most water year types. In November, the percentage of days above the thermal threshold has dropped to less than 5 percent (critical years) and by December there are no modeled exceedances of the thermal threshold of 63°F in any water year type. The modeled water temperatures indicate that there will be very high percentages of times when the thermal thresholds will be exceeded over the summer months at the Watt Avenue location, implying that steelhead juveniles rearing in this reach will have a high likelihood of low fitness or possibly death from high water temperature exposure if they remain in this reach.

Like the 63°F threshold discussed above, the modeling of water temperatures during the winter months (January through March) indicate that there are no days with exceedances above the 69°F 7DADM threshold and therefore, juvenile steelhead would rear under optimal thermal conditions in the river reach containing the Watt Avenue location during this period. By April, the water temperatures in the Watt Avenue reach are modeled to begin increasing and exceed the 69°F 7DADM threshold, primarily in below normal and critical water year types. By May, the modeling implies that approximately 26 to 28 percent of days in below normal and dry years exceed the thermal threshold, and up to 50 percent of days in critical years. During the summer period (June through September) the percentage of exceedances increases, reaching approximately 80 percent to 85 percent in July, and 90 percent to 95 percent in August for drier water year types. In September, the number of days with threshold exceedances are still high, particularly for drier water year types and reach approximately 95 percent in critical water year types. In October, modeled water temperatures begin to decrease and the percentage of days above the 69°F 7DADM threshold decreases substantially. However, in critical water year types, the percentage of days exceeding the threshold still ranges between 38.4 percent (PA) to 47.0 percent (NAA). By November and December, the modeled water temperatures have cooled sufficiently to avoid any exceedances of the thermal threshold. As discussed above, the water temperature modeling for the Watt Avenue reach during the summer period (June through September) indicates that thermal conditions will be detrimental to the rearing of steelhead juveniles based on the 69°F 7DADM threshold, leading to an increased risk of reduced fitness or mortality.

NMFS finds that the water temperature conditions under both the PA and NAA operational scenarios will adversely affect the rearing of juvenile steelhead in the American River from Hazel Avenue downstream to the confluence, including Watt Avenue from June through October, with particularly deleterious conditions over the summer from July through September.

An additional threshold analysis was conducted to determine how the PA would affect smoltification. A 54°F threshold was used, based on an average of temperatures from Zaugg and Wagner (1973), Adams et al (1975), Zaugg (1981), and Hoar (1988), and above which smoltification can be impaired. This analysis was conducted for January through March in the reach from Hazel Avenue to Watt Avenue.

Results of the water temperature thresholds analysis for steelhead smoltification are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-173 and 5.D-174. At Hazel Avenue and Watt Avenue, there would be no months or water year types with either a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or a more-than-0.5°F difference in the magnitude of average daily exceedance. However, the water temperature modeling also indicates that water temperature values will increase in February and March at both locations and increase the percentage of days in which the ambient water temperature exceeds the 54°F thermal threshold for optimal smoltification. At Hazel Avenue, water temperatures begin to exceed the thermal threshold in March in below normal, dry, and critical years. There is a minimal risk in below normal years, as measured by the percentage of days that will exceed the threshold (0.9 percent NAA, 0.6 percent PA), but the risk increases to 6.6 percent (NAA) and 6.8 percent (PA) in dry years, and 16.7 percent (NAA) and 13.4 percent (PA) in critical years. At the Watt Avenue location farther downstream, the number of days exceeding the thermal threshold is 13.2 percent (NAA) and 13.8 percent (PA) in critical years in February, and ranges from approximately 2 percent in wet years to approximately 70 percent in critical years in March. The modeling implies that successful smoltification may be hindered in March in drier years, but in particular during critical water year types under both the PA and NAA modeling scenarios.

NMFS finds that the water temperature conditions under both the PA and NAA from February through March will adversely affect smoltification of steelhead juveniles in the American River based on the modeling conducted. These adverse effects are more frequent and prevalent in drier water year types.

Smolt Emigration

Modeled mean monthly water temperatures in the American River in the reach from Hazel Avenue to Watt Avenue during the December through June smolt emigration period, with a peak during January through March are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-14, Table 5.C.7-15. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) throughout the American River in the reach from Hazel Avenue to Watt Avenue in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.4°F (0.5 to 0.6 percent), and would occur at Hazel Avenue during June of above normal water years and at Watt Avenue in June of critical years. These largest increases would be outside the peak period of smolt emigration.

Exceedance plots of mean monthly water temperatures were examined during each month and water year type throughout the smolt emigration period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The curves for PA generally match those of the NAA. Further examination of June of above normal water years at Hazel Avenue (Figure **Error! No text of specified style in document.**-11) and in June of critical years at Watt Avenue (Figure **Error! No text of specified style in document.**-12), where the largest increases in mean monthly water temperatures were seen, reveals that the curves were mostly similar overall with the exception of a few differences of more than 1°F in the middle of the range.

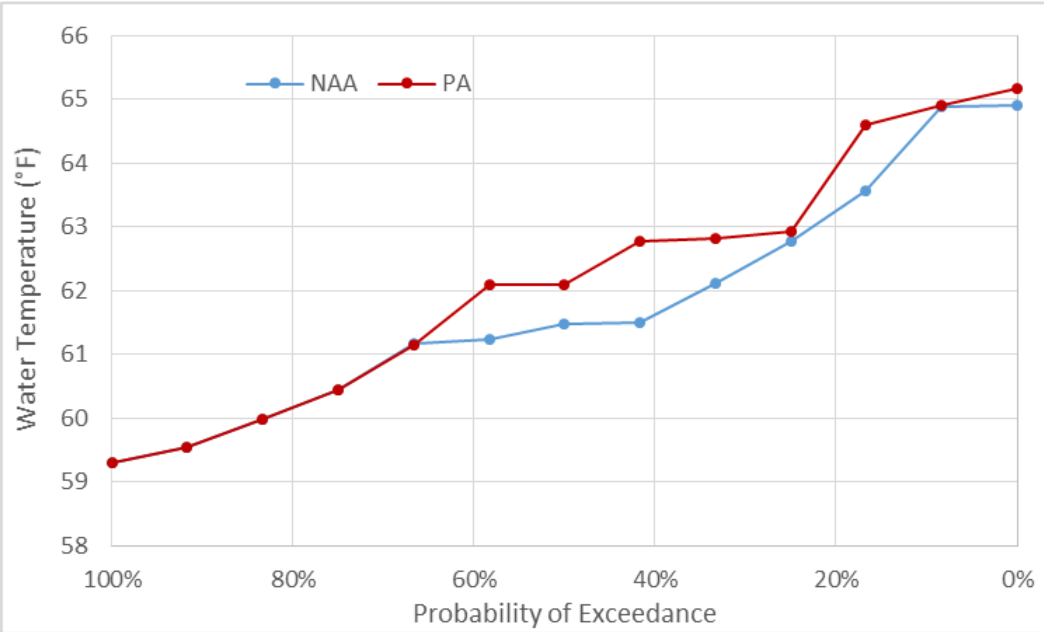

Figure ***Error! No text of specified style in document.****-11. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Hazel Avenue in June of Above Normal Water Years*

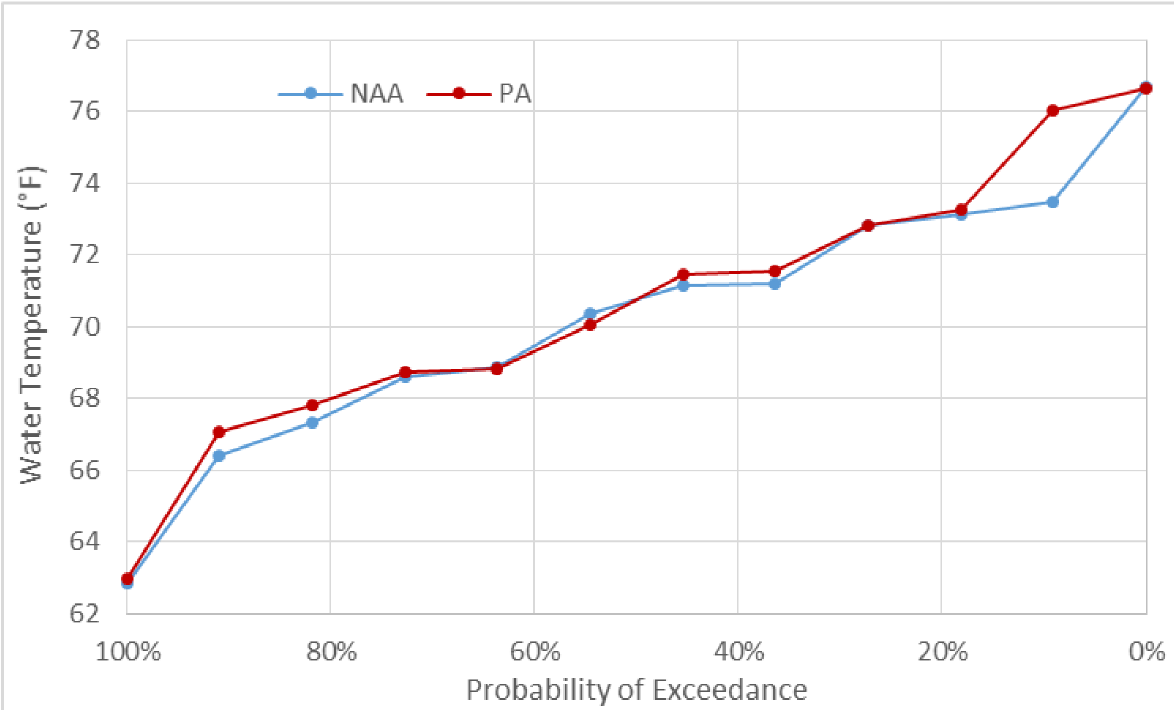

*Figure **Error! No text of specified style in document.**-12. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in June of Critical Water Years*

The exceedance of temperature thresholds in the American River between Hazel Avenue and Watt Avenue presented in the BA in Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-50 by modeled daily water temperatures were evaluated based on thresholds identified in USEPA's temperature water quality guidance (U.S. Environmental Protection Agency 2003). Two thresholds, 61°F 7DADM and 64°F 7DADM, were evaluated. The 61°F value represents the core, defined by U.S. Environmental Protection Agency (2003) as "moderate to high density", location of Hazel Avenue and the 64°F value represents non-core, defined by U.S. Environmental Protection Agency (2003) as "low to moderate density", location of Watt Avenue. The 7DADM values were converted by month to function with daily model outputs (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-52).

Results of the water temperature thresholds analysis for steelhead smolt emigration are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5-D-171 and Table 5.D-172. At both Hazel Avenue and Watt Avenue, there would be no months or water year types with a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or with a more-than-0.5°F difference in the magnitude of average daily exceedance. Based on the modeling, no exceedances of the 61°F 7DADM will occur during the peak of the smolt emigration period (January through March) at the Hazel Avenue location. Daily thermal threshold exceedances at Hazel Avenue will begin in April in below normal, dry, and critical water year types with typically less than 10 percent of the days exceeding the threshold. By May, exceedances occur in all water year types, but will be highest in drier water years, reaching approximately 43 percent in below and dry years, and 65 percent in critical years. By June, all water years types are expected to see at least 25 percent of the days exceeding the thermal threshold, with critical years surpassing 90 percent of the days. The Watt Avenue location data indicates that there will be no daily exceedances during the peak smolt emigration months of January through March. Daily exceedances begin in April, as seen in the Hazel Avenue data, but are greater in magnitude. Daily exceedances in April are at least 14 percent in dry years and reach approximately 37 percent in critical years. By May more than half of the days are expected to exceed the thermal threshold with the exception of wet years (18 percent exceedance). This data implies that steelhead smolts that emigrate prior to April should have thermal conditions that are protective and conducive to successful outmigration. Those fish which emigrate later in the spring will do so under degraded thermal conditions that are likely to reduce their fitness and viability. Overall, the modeling data suggests that the emigration of steelhead smolts will be minimally affected by water temperatures exceeding the EPA thresholds of 61^{o}F 7DADM or 64^{o}F 7DADM for core and non-core areas, respectively.

NMFS finds that the water temperature conditions under both the PA and NAA from January through March will not adversely affect the migration of steelhead smolts in the American River based on the modeling conducted and the thresholds for the core areas (61^{o}F 7DADM) and non-core areas (64^{o}F 7DADM) analyzed. In contrast, thermal conditions in April, May, and June, as modeled for the PA and NAA operational conditions, create adverse effects for emigrating steelhead smolts leaving the American River after the peak emigration period.

Adult Immigration

Modeled mean monthly water temperatures in the American River at Hazel Avenue and Watt Avenue during the October through April adult immigration period for steelhead are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-14, Table 5.C.7-15. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F (0.4 percent), and would occur at Hazel Avenue during October of above normal water years, and at Watt Avenue during March of critical water years and October of above normal water years.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult immigration period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA period. Further examination of October of above normal water years at Hazel Avenue (Figure 5.4 268), March of critical water years at Watt Avenue (Figure 5.4 264), and October of above normal water years at Watt Avenue (Figure 5.4 269), where the largest increases in mean monthly water temperatures were seen, reveals that the curves were largely similar overall and that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in each exceedance plot. A difference of 0.2°F is likely within the uncertainty of the CALSIM and HEC5Q models, as described in the BA in Appendix 5.A, *CALSIM Methods and Results*, Section 5.A.4.5, *Limitations and Appropriate Use of Model Results*, and Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.2.5, *Model Limitations*. One exception would be at Hazel Avenue in October of above normal water years, in which there would be 2 years during which water temperatures under the PA would be approximately 1°F higher than those under the

NAA (Figure 5.4 268). Further examination of these years reveals that this appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs and there are no operational requirements, such as cold-water pool storage, temperature, or outflow requirements, that would cause these years to differ so widely in water temperatures. Mean Folsom September storage under the PA would be similar (less than 5 percent difference) to storage under NAA for all water year types, except for 8 percent lower mean storage during dry water years under the PA (BA Appendix 5.A, *CALSIM Methods and Results*).Therefore, there is no practical reason why actual operations under the PA would be different from those under the NAA in these months and years.

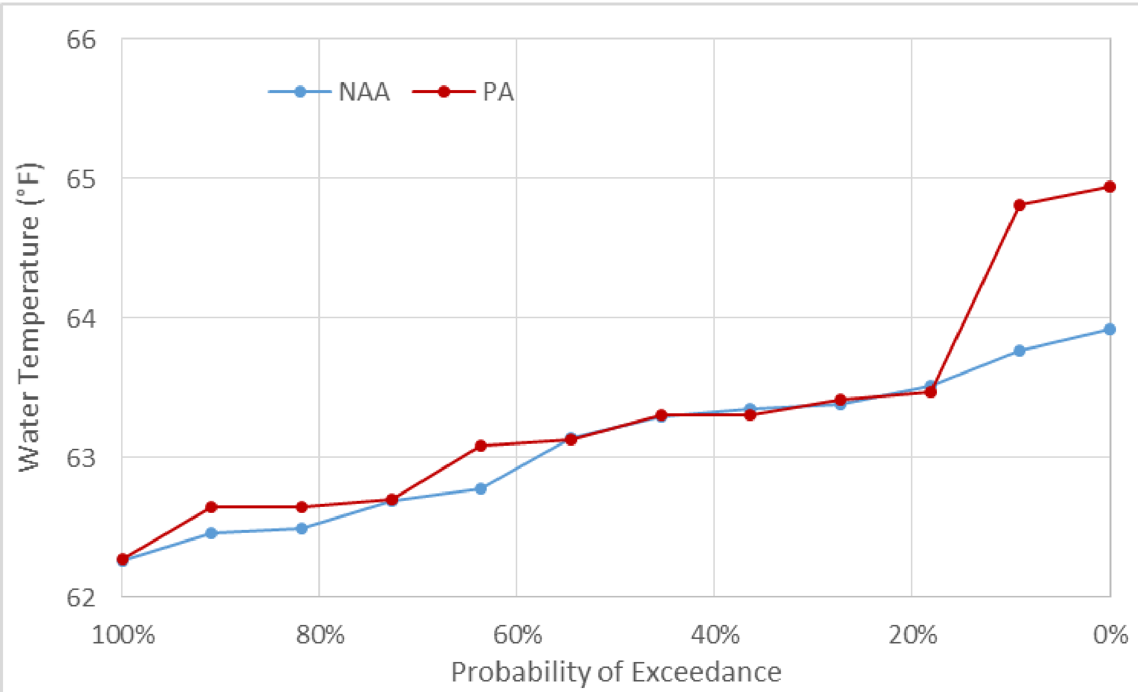

Figure ***Error! No text of specified style in document.****-13. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Hazel Avenue in October of Above Normal Water Years*

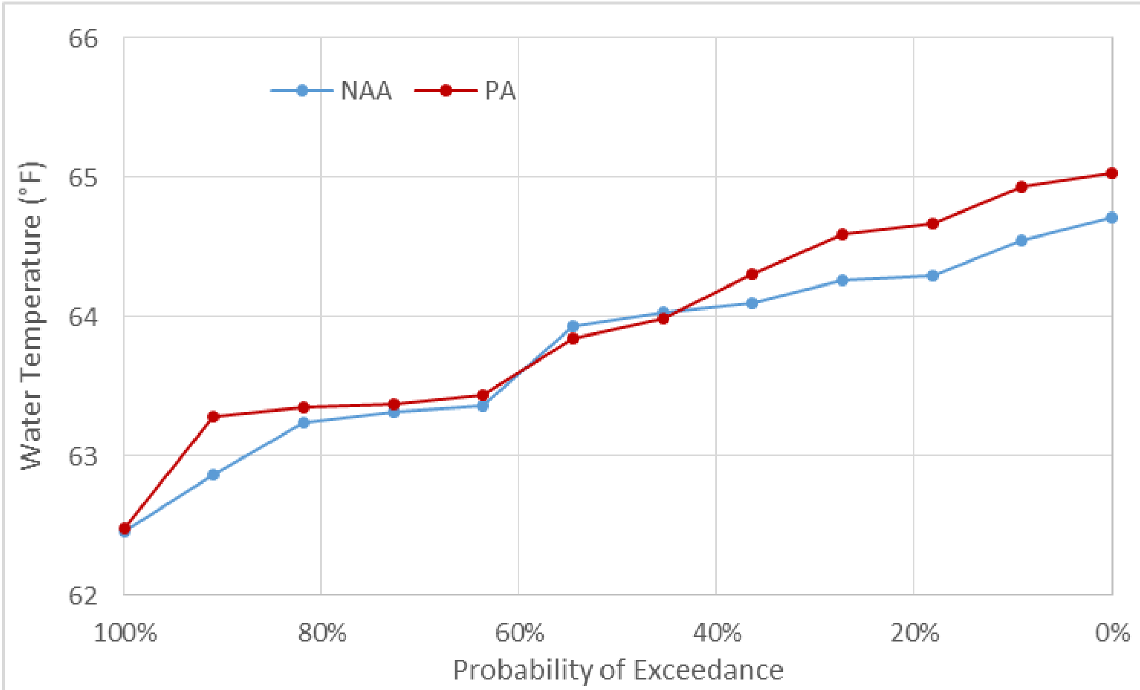

Figure ***Error! No text of specified style in document.****-14. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in October of Above Normal Water Years*

To evaluate water temperature threshold exceedance during the steelhead adult immigration life stage at Hazel Avenue and Watt Avenue, thresholds of 68°F 7DADM and 70°F were used (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-50). The 68°F 7DADM threshold was taken from U.S. Environmental Protection Agency (2003) and the 70°F threshold represents the average of the studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range. The 7DADM threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-52).

Results of the water temperature thresholds analysis for adult steelhead immigration are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-175 through Table 5.D-178. At both Hazel Avenue and Watt Avenue, there would be no months or water year types with a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or with a more-than-0.5°F difference in the magnitude of average daily exceedance. The modeling data shows that there are no days that are expected to exceed the 68°F 7DADM thermal threshold from November through April at the Hazel Avenue location under any water year type. Exceedances are only observed in the modeled scenarios in October, and then primarily in critical water years when approximately 20 to 22 percent of the days will exceed the thermal threshold. Exceedances in October occur in below normal and dry years and no more than approximately 5 percent of the days in the month are expected to exceed the threshold. The modeling for the 70°F threshold at Hazel Avenue shows that the water temperatures are not expected to exceed this threshold in any month between October and April under in any water year type. Therefore, water temperatures are not expected to negatively impact adult immigration of steelhead in the American River reach occupied by the Hazel Avenue location except during October of critical water years using the lower 68°F thermal threshold standard.

The modeling of water temperatures at Watt Avenue indicates that the 68°F 7DADM thermal threshold will be exceeded in both October and April. All water year types will have exceedances in October, with the percentage of days exceeding the threshold increasing with drier water year types. Wet and above normal years will have less than 14 percent exceedances of the threshold. The percent exceedances will increase to approximately 23 percent in below normal years, 32 percent in dry years and between 55 percent (PA) and 62 percent (NAA) in critical years. The month of April will have low numbers of days that will exceed the thermal threshold, increasing with drier water year types up to approximately 10 percent in critical years. The modeling results using the higher 70°F threshold substantially reduce the number of days that will exceed the threshold. Exceedances occur primarily in the critical years in October, and then are less than 11 percent of the days in October. The other water years are less than 2 percent in October. There is a negligible level of exceedances above thermal threshold in April in critical years (0.6 percent). The modeling implies that most of the immigration period for adult steelhead in the American River will not be affected by thermal conditions except for October at the Watt Avenue location. Fish that move upriver after October should see conditions that are favorable to upstream movements.

NMFS finds that the thermal conditions under both the PA and NAA operational scenarios will adversely affect adult migration at Watt Avenue and Hazel Avenue in October, particularly in drier years and especially critically dry years, and to a lesser degree in April, based on the lower thermal threshold of 68°F 7DADM. The higher threshold of 70°F will have a lower level of adverse effects on adult migration in these two months. NMFS finds that there will be no adverse effects if the 70°F threshold is used at the Hazel Avenue location, and a limited adverse effect at the Watt Avenue location for this more lenient threshold.

Adult Holding

Modeled mean monthly water temperatures in the American River at Hazel Avenue and Watt Avenue during the October and November steelhead adult holding period are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-14, Table 5.C.7-15. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F (0.4 percent), and would occur at both locations during October of above normal water years.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult holding period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of October in above normal years at Watt Avenue (Figure 5.4 267), where the largest increase in mean monthly water temperatures were seen, reveals that the curves were largely similar overall and that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in the exceedance plot. A difference of 0.2°F is likely within the uncertainty of the CALSIM and HEC5Q models, as described in the BA in Appendix 5.A, *CALSIM Methods and Results*, Section

5.A.4.5, *Limitations and Appropriate Use of Model Results*, and Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.2.5, *Model Limitations*. Further examination of October of above normal water years at Hazel Avenue (Figure 5.4 266), also where the largest increase in mean monthly water temperatures were seen, reveals that there would be 2 years during which water temperatures under the PA would be approximately 1°F higher than those under the NAA. However, upon closer examination, this is appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs and there are no operational requirements, such as cold-water pool storage, temperature, or outflow requirements, that would cause these years to differ so widely in water temperatures.

To evaluate water temperature threshold exceedance during the steelhead adult holding life stage at Hazel Avenue and Watt Avenue, the USEPA's 7DADM threshold value of 61°F was used in the BA in Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-50) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-52).

Results of the water temperature thresholds analysis for adult steelhead holding are presented in the BA in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-179 and 5.D-180. At both Hazel Avenue and Watt Avenue, there would be no months or water year types with a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or with a more-than-0.5°F difference in the magnitude of average daily exceedance. The modeling data indicates that at the Hazel Avenue location, the percentage of daily exceedances above the 61ºF 7DADM would occur in all water year types in the months of October and November. In October, exceedances range from approximately 68 percent of the days in wet year types to approximately 100 percent of the days in critical year types. November has substantially less days in which the thermal threshold is exceeded, ranging from approximately 5 percent of the days in a wet year to approximately 15 percent in critical years. The downstream location at Watt Avenue shows a greater percentage of days in which the thermal threshold is exceeded during the adult holding period in October and November. In October, the number of days in which the thermal threshold is exceeded range from approximately 93 percent in wet years to 100 percent in the dry and critical year types. Like Hazel Avenue, November has less days in which the thermal threshold is exceeded, but the more downstream location of Watt Avenue has a greater proportion of days exceeding the threshold. The number of days in which the threshold is exceeded range from approximately 10 percent in wet years to 30 percent in critical years. This modeling for the river temperatures at Watt and Hazel Avenues implies that adult steelhead holding at either location in October will experience substantial risk for damage to their gametes and overall fitness prior to spawning. The thermal conditions in November show improvements based on the modeling, but a still substantial proportion of the population is at risk in drier years.

NMFS finds that there will be substantial adverse effects to holding adult steelhead at the Watt Avenue location in the months of October and to a lesser extent in November based on the thermal threshold of 61ºF 7DADM. Adult steelhead holding at the Hazel Avenue location will have substantial adverse effects related to the thermal conditions of the PA and NAA operational conditions in the months of October and to a lesser extent in November.

2.5.1.2.1.4 Green Sturgeon Exposure and Risk

Water temperature is likely a key factor in sturgeon recruitment and development. Lab-based data from the nDPS indicate that eggs hatch after 144-192 hours when incubated at a temperature of 15.7 ± 0.02°C (Deng et al. 2002). Van Eenennaam et al. (2005) found that the hatching rate for green sturgeon eggs was slightly reduced when incubation temperatures were less than 11°C. They also found that the upper lethal temperature for developing embryos to be approximately 22-23°C, with sub-lethal effects from 17.5 to 22.2°C (Van Eenennaam et al. 2005). In the laboratory, metamorphosis from larvae to juvenile of Northern DPS green sturgeon occurred at approximately 45 days post-hatch, at lengths of 62-94 mm (Deng et al. 2002). Based on these temperature thresholds and requirements for the early life stages of this species, the predicted range of water temperatures in the upper Sacramento River following implementation of the PA is not expected to adversely affect the reproductive success, growth, or survival of sDPS green sturgeon.

2.5.1.2.1.5 Fall/Late fall-run Exposure and Risk

2.5.1.2.1.5.1 Sacramento River

2.5.1.2.1.5.1.1 Fall-run Chinook Salmon

Fall-run Chinook salmon exposure and risk to warm water temperatures occurring in the Sacramento River under the PA are discussed below by life stage in the following order: (1) spawning, egg incubation, and alevin development; (2) fry and juvenile rearing and outmigration; and (3) adult immigration and holding.

Spawning, egg incubation, and alevin

Sacramento River fall-run Chinook salmon spawn from Keswick Dam to Princeton Ferry, with the vast majority (i.e., 94 percent) occurring upstream from Tehama Bridge at RM X (Table 2-3). Fall-run Chinook salmon eggs and alevins occur in the Sacramento River from the time when spawning begins in September through fry emergence in January (Vogel and Marine 1991).

Table ***Error! No text of specified style in document.****-3. Spatial Distribution of Spawning Redds in the Sacramento River Based on Aerial Redd Surveys, Fall-Run Chinook Salmon, 2003–2014 (Source: BA; initial source is CDFW)*

Reach	Mean Annual Percent of Total Redds Sighted
Keswick to ACID Dam	16.3
ACID Dam to Highway 44 Bridge	5.5
Highway 44 Bridge to Airport Road Bridge	12.3
Airport Rd. Bridge to Balls Ferry Bridge	16.2
Balls Ferry Bridge to Battle Creek	10.3
Battle Creek to Jelly's Ferry Bridge	12.7
Jelly's Ferry Bridge to Bend Bridge	6.6
Bend Bridge to Red Bluff Diversion Dam	3.5
Red Bluff Diversion Dam to Tehama Br.	10.8
Tehama Br. To Woodson Bridge	3.1
Woodson Bridge to Hamilton City Br.	1.8
Hamilton City Bridge to Ord Ferry Br.	0.8
Ord Ferry Br. To Princeton Ferry.	0.1
ACID = Anderson-Cottonwood Irrigation District	

Mean monthly water temperatures during the September through January spawning, egg incubation, and alevins period for fall-run Chinook salmon, with peak presence of October through December are presented in the BA in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. As stated in the BA, overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately a one percent change) from Keswick to Red Bluff in all months of the period and water year types. The largest increase in mean monthly water temperatures under the PA relative to the NAA would be 0.7°F, or up to one percent, and would occur at Red Bluff in wet and above normal years during September. These largest increases would not overlap spatially or temporally with peak fall-run Chinook salmon spawning, which occurs upstream from Red Bluff in October and November.

Exceedance plots of monthly mean water temperatures were examined during each month and water year type throughout the spawning and incubation period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The curves for the PA generally overlap those of the NAA. Further examination of above normal (Figure **Error! No text of specified style in document.**-15) and below normal years during September at Red Bluff (Figure **Error! No text of specified style in document.**-16) and in below normal years during September at Bend Bridge (Figure **Error! No text of specified style in document.**-17), where the largest modeled increases in mean monthly water temperatures due to the PA were found, reveals that water temperatures under the PA are almost always slightly warmer than under the NAA, with typically less than a degree (F) difference between the two alternatives.

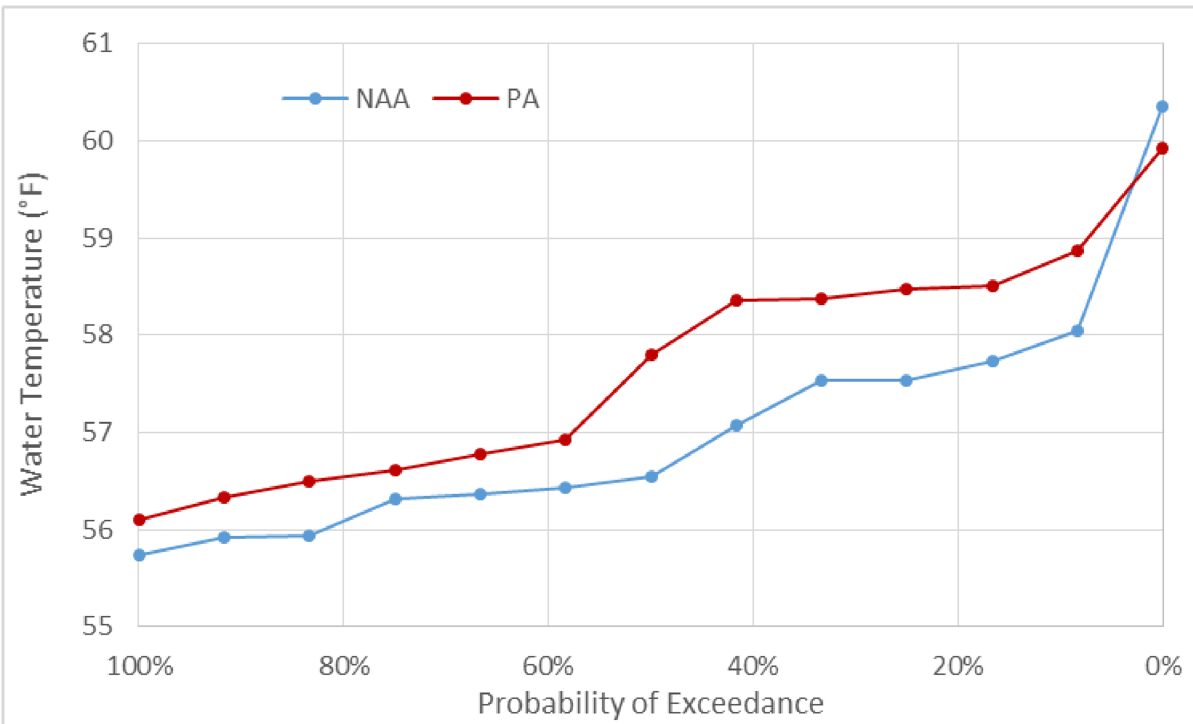

*Figure **Error! No text of specified style in document.**-15. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Above Normal Water Years*

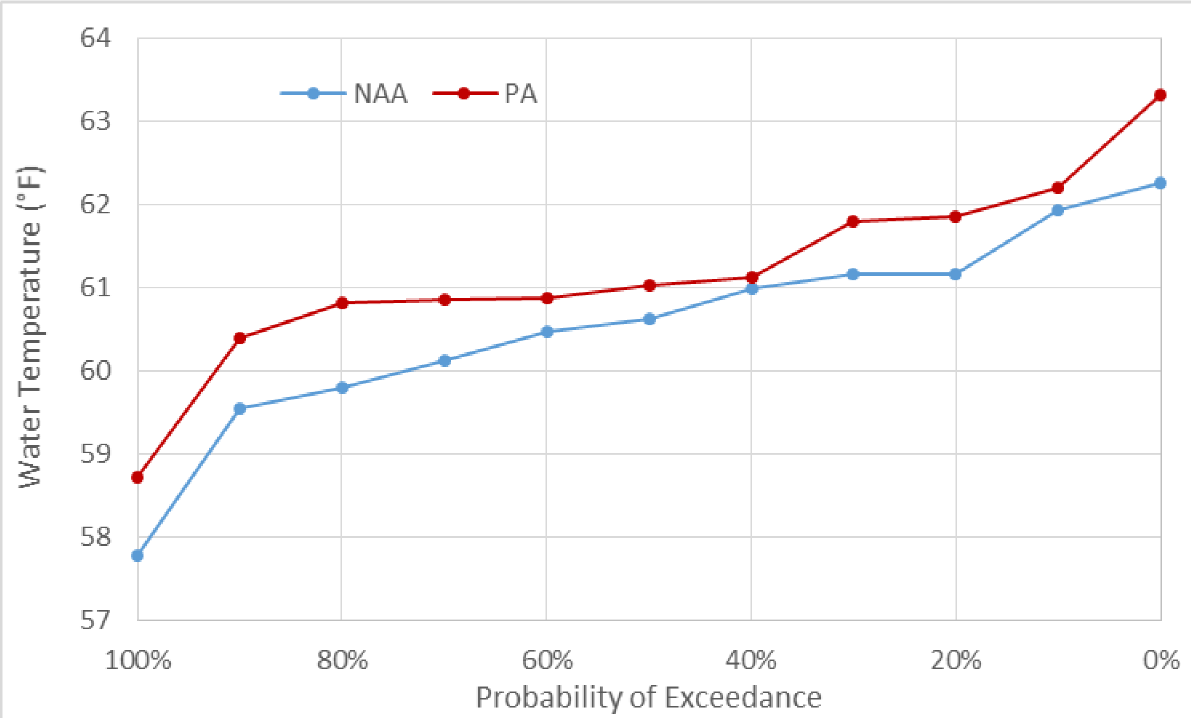

*Figure **Error! No text of specified style in document.**-16. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Below Normal Water Years*

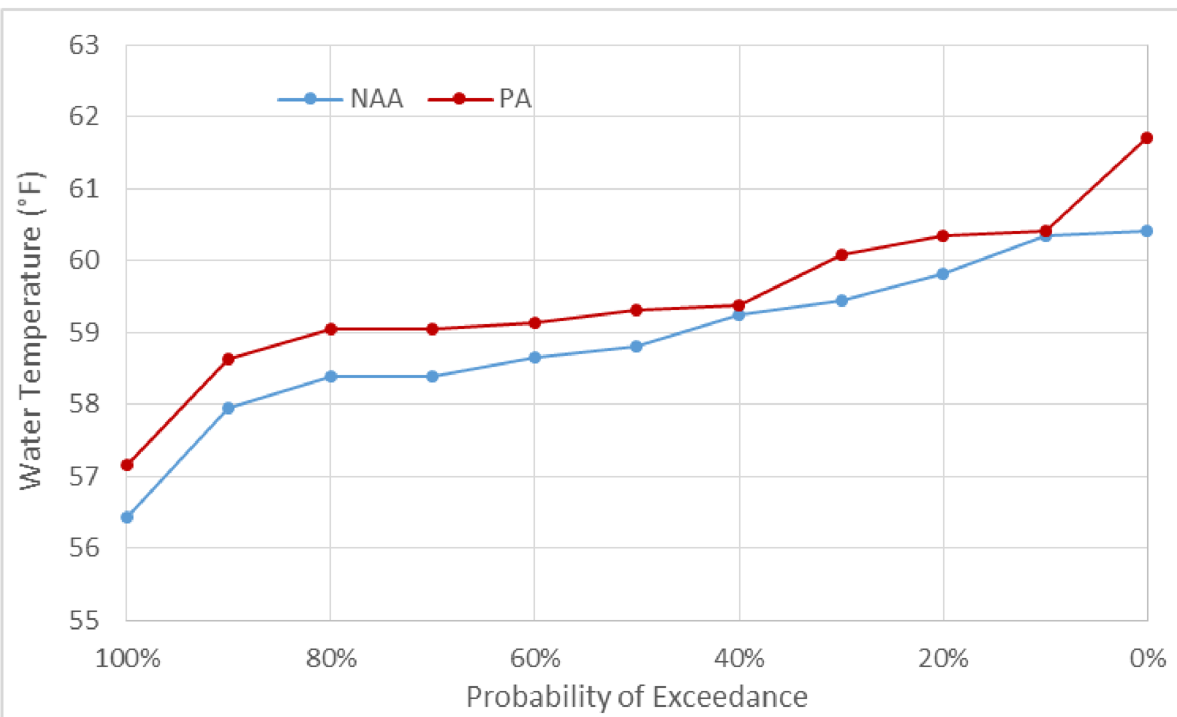

*Figure **Error! No text of specified style in document.**-17. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in September of Below Normal Water Years*

The water temperature exceedance plots are useful for assessing whether the PA is expected to make conditions warmer, colder, or have little impact relative to the NAA. The plots clearly show that the latter (little impact) is the case. What the plots do not show is how fish life stages, in this case fall-run Chinook salmon eggs and alevins, will be affected by the PA thermal regime.

To take the analysis a step further and evaluate how PA water temperatures are expected to affect fall-run Chinook salmon egg incubation and alevin development, we looked at results of the NMFS Southwest Fisheries Science Center's newly developed egg mortality model (Martin et al. in review), as well as results from two biological analyses presented in the BA – a water temperature thresholds analysis and SALMOD. Overall, because the three biological tools utilize daily (thresholds analysis and the egg/alevin mortality model) or weekly (SALMOD) water temperatures downscaled from modeled monthly values, the certainty of their respective abilities to accurately estimate thermal impacts to eggs and alevins in the Sacramento River with implementation of the PA is low[4]. Eggs and alevins developing in the Sacramento River spawning gravels experience a thermal regime that varies between day and night and from one day to the next. The water temperature modeling utilized in the biological models does not capture that level of thermal variation. Nevertheless, the biological models are useful quantitative indicators of potential thermal impacts under the PA. Below the SWFSC's egg mortality model, the thresholds analysis, and SALMOD are discussed in that order.

The SWFSC egg mortality model, described above in the winter-run Chinook salmon section, was linked with a 1-dimensional temperature model of the Sacramento River with one km spatial resolution (Pike et al. 2013) to estimate daily survival probabilities for eggs when exposed to water temperatures under the PA and NAA. Figure X4 shows the fall-run Chinook salmon egg survival probability under the PA and NAA for all water years combined and by water year type. These results show the survival after accounting for only the effects of water temperature. Other factors affecting egg and alevin survival such as physical disturbance from redd superimposition would lower the water temperature dependent survival shown in Figure X4.

Fall-run Chinook salmon egg survival is expected to be less than 50% throughout much of the spawning habitat in September and early October in all water years under either alternative. In critical water years, egg survival would be less than 10% throughout the spawning habitat for all of September and the beginning of October. Even in the wetter water years, egg survival in that time frame is less than 50% except for the first few kilometers. These results suggest that Sacramento River water temperatures under the PA or the NAA will have an adverse effect on fall-run Chinook salmon egg incubation.

[4] Additional key assumptions and data limitations that influence the reliability of results from SALMOD are highlighted in NRC (2010).

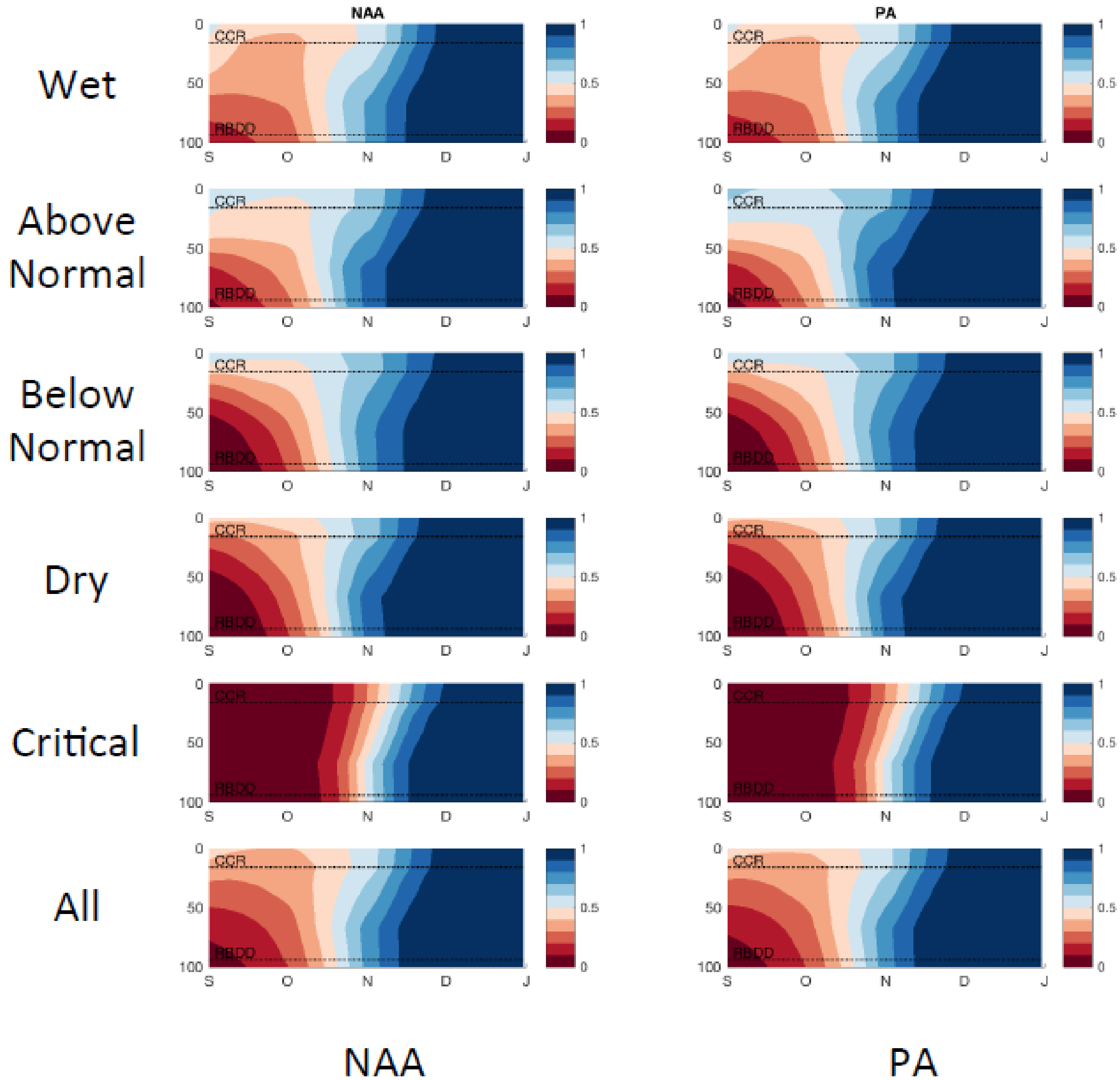

Figure X4. Fall-run Chinook salmon egg survival landscape from the SWFSC's temperature dependent egg survival model. Primary Y-axis is distance in km downstream from Keswick Dam. The color key is the probability of survival.

The water temperature thresholds analysis presented in the BA provides another indication that water temperatures under the PA are expected to have an adverse effect on fall-run Chinook salmon spawning, egg incubation, and alevin development. As pointed out in the BA (pages 5.E-153 and 5.E-154), the differences in the percent of days above the spawning, egg, and alevin water temperature threshold (i.e., 55.4 7DADM) between the NAA and the PA would be minimal across months, locations, and water year types (BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Table 5.E.1-1 through 5.E.1-5). However, adverse effects to fall-run Chinook salmon eggs under either the NAA or PA are expected to occur in every single year regardless of water year type. That is because water temperatures are frequently expected to exceed 55.4F 7DADM for a long duration during peak spawning and egg incubation months over a range of hydrologic conditions. For example, the water temperature threshold analysis shows that even in wet years at the Keswick Dam gauge, water temperatures under the PA will exceed the temperature threshold for 61 percent of the days in November (Table 5.E.1-1). The longer the duration of exposure to water temperatures that are warmer than the threshold, the greater the severity of adverse effects. Conditions worsen further downstream at the Clear Creek, Balls Ferry, Bend Bridge, and Red Bluff locations, particularly in October, with PA water temperatures exceeding the egg and alevin threshold (i.e., 55.4F 7DADM) for 82 percent to 100 percent of the days across all water year types. From a qualitative context, egg and alevin mortality above natural levels (i.e., little to no thermal stress) is expected under such a thermal regime, and that is what the quantitative biological models (SWFSC's egg mortality model and SALMOD) predict as well.

The SALMOD model predicts water temperature-related mortality of fall-run Chinook salmon eggs and alevins the Sacramento River. This water temperature-related mortality is split up as pre-spawn (in vivo, or in the mother before spawning) and egg (in the gravel) mortality (see BA Attachment 5.D.2, SALMOD Model, for a full description). Table 5.E-37 presents results for water temperature-related mortality of spawning, eggs, and alevins, in addition to all sources of mortality for fall-run Chinook salmon predicted by SALMOD discussed in other sections of this document. Mean annual egg and alevin mortality under the PA predicted by SALMOD ranges from 182,221 in below normal water years to 18,248,020 in critical water years. For all water year types combined, mean annual egg and alevin mortality under the PA is estimated at 5,683,877. When mortality from redd dewatering, redd scour, and redd superimposition are added to the temperature-related mortality, the mean annual egg and alevin mortality under the PA ranges from 485,979 in below normal water years to 18,625,799in critical water years (Table **Error! No text of specified style in document.**-4).

*Table **Error! No text of specified style in document.**-4. Mean Annual Fall-Run Chinook Salmon Mortality (# of Fish/Year) Predicted by SALMOD*

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing									
	Temperature-Related Mortality			Flow-Related Mortality				Temperature-Related Mortality				Flow-Related Mortality					
Analysis Period	Pre-Spawn	Eggs	Subtotal	Incubation	Super-imposition	Subtotal	Life Stage Total	Fry	Pre-smolt	Immature Smolt	Subtotal	Fry	Pre-smolt	Immature Smolt	Subtotal	Life Stage Total	Grand Total
All Water Year Types[1]																	
NAA	5,144,855	809,484	5,954,338	1,451,660	511,012	1,962,672	7,917,010	150	4,296	6,055	10,501	4,694,051	266,976	40,366	5,001,393	5,011,894	12,928,904
PA	5,022,884	660,993	5,683,877	1,477,164	550,222	2,027,386	7,711,263	160	3,305	5,350	8,814	4,716,470	267,867	41,632	5,025,968	5,034,783	12,746,046
Difference	-121,970	-148,491	-270,461	25,504	39,210	64,714	-205,747	10	-991	-705	-1,687	22,419	891	1,265	24,575	22,889	-182,859
Percent Difference[3]	-2	-18	-5	2	8	3	-3	6	-23	-12	-16	0	0	3	0	0	-1
Water Year Types[2]																	
Wet (32.5%)																	
NAA	224,282	724,794	949,076	4,013,334	1,304,607	5,317,941	6,267,017	419	4,344	1,216	5,980	5,142,369	77,086	14,964	5,234,419	5,240,399	11,507,415
PA	81,977	213,648	295,625	4,066,702	1,436,450	5,503,152	5,798,777	472	4,231	1,943	6,645	5,194,728	75,562	16,386	5,286,676	5,293,321	11,092,098
Difference	-142,305	-511,146	-653,451	53,368	131,843	185,212	-468,240	52	-113	726	666	52,359	-1,525	1,422	52,256	52,922	-415,318
Percent Difference	-63	-71	-69	1	10	3	-7	13	-3	60	11	1	-2	10	1	1	-4
Above Normal (12.5%)																	
NAA	9,090,676	497,965	9,588,640	63,475	688,815	752,290	10,340,930	20	2,720	987	3,726	5,001,065	116,203	25,093	5,142,361	5,146,087	15,487,018
PA	9,476,226	106,985	9,583,211	94,913	675,539	770,452	10,353,663	19	2,397	1,086	3,502	5,134,558	124,860	26,228	5,285,646	5,289,147	15,642,810
Difference	385,550	-390,980	-5,430	31,439	-13,276	18,162	12,732	-1	-322	99	-224	133,493	8,656	1,135	143,284	143,060	155,792
Percent Difference	4	-79	0	50	-2	2	0	-5	-12	10	-6	3	7	5	3	3	1
Below Normal (17.5%)																	
NAA	57,594	127,629	185,223	306,984	0	306,984	492,207	0	571	872	1,443	5,201,156	404,885	55,474	5,661,515	5,662,958	6,155,165
PA	57,234	124,986	182,221	303,758	0	303,758	485,979	0	514	911	1,426	5,188,265	397,816	61,171	5,647,252	5,648,678	6,134,656
Difference	-360	-2,643	-3,003	-3,226	0	-3,226	-6,228	0	-56	39	-18	-12,890	-7,070	5,697	-14,263	-14,281	-20,509
Percent Difference	-1	-2	-2	-1	0	-1	-1	0	-10	4	-1	0	-2	10	0	0	0
Dry (22.5%)																	
NAA	4,432,070	732,312	5,164,382	364,687	0	364,687	5,529,069	65	2,706	1,662	4,434	4,607,491	443,967	57,263	5,108,721	5,113,155	10,642,224
PA	4,421,190	1,145,829	5,567,018	374,597	0	374,597	5,941,615	38	1,957	841	2,837	4,464,993	455,957	56,178	4,977,128	4,979,965	10,921,580
Difference	-10,880	413,517	402,637	9,910	0	9,910	412,546	-27	-749	-821	-1,597	-142,498	11,990	-1,086	-131,593	-133,190	279,356
Percent Difference	0	56	8	3	0	3	7	-41	-28	-49	-36	-3	3	-2	-3	-3	3
Critical (15%)																	
NAA	17,301,522	2,051,093	19,352,615	363,933	0	363,933	19,716,548	0	11,836	33,277	45,112	3,132,461	391,949	66,552	3,590,961	3,636,073	23,352,621
PA	16,417,771	1,830,250	18,248,020	377,779	0	377,779	18,625,799	0	7,087	28,295	35,382	3,288,656	378,908	67,477	3,735,041	3,770,423	22,396,222
B Difference	-883,752	-220,843	-1,104,595	13,846	0	13,846	-1,090,749	0	-4,748	-4,982	-9,730	156,195	-13,040	926	144,080	134,350	-956,399
Percent Difference	-5	-11	-6	4	0	4	-6	0	-40	-15	-22	5	-3	1	4	4	-4

1 Mortality values do not include base mortality
2 Based on the 80-year simulation period
3 Relative difference of the Annual average
4 As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB 1995). Water years may not correspond to the biological years in SALMOD.
5 NA = Unable to calculate because dividing by 0

Results of the SWFSC egg mortality model, the water temperature thresholds analysis, and SALMOD all suggest that water temperatures under the PA are expected to have an adverse effect on fall-run Chinook salmon spawning, egg incubation, and alevin development.

Fry, Juvenile Rearing and Outmigration

Mean monthly water temperatures during the December through June fry and juvenile rearing period for fall-run Chinook salmon in the Sacramento River upstream of the Delta are nearly identical between the PA and NAA (see BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10). Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) throughout the juvenile rearing reach of Keswick to Knights Landing in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.3°F (0.5 percent to 0.7 percent), and would occur at Keswick, above Clear Creek, Balls Ferry, and Bend Bridge in below normal years during May, which is outside the peak period of presence for fall- run Chinook salmon fry and juveniles.

As presented in the BA, the water temperature thresholds analysis for fall-run Chinook salmon juvenile rearing and emigration have been combined and the period of December through June was evaluated. The threshold used was from the USEPA's 7DADM value of 61°F for the core juvenile rearing reach from Keswick to Red Bluff and 64°F for the non-core juvenile rearing reach at Knights Landing (BA Table 5.E-22). The 7DADM values were converted by month to function with daily model outputs (see BA Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-4).

Results of the water temperature thresholds analysis indicate that an adverse effect to fall-run Chinook salmon juveniles is expected under the PA's thermal regime (Tables 5.E.1-9 through 5.E.1-11. The general pattern is that daily occurrences of threshold exceedances under the PA increase as fish move downstream from Balls Ferry and as the season progresses from April through June. As such, the frequency of adverse effects to fall-run Chinook salmon juveniles are expected to increase from Balls Ferry downstream to Knights Landing and from month to month during the April through June period. The mean percentage of days for all water years combined where April through June water temperatures under the PA are expected to exceed the 7DADM thresholds (61°F for core, 64°F for non-core) during ranges from 0.1 percent up to 6.9 percent at Bend Bridge; from 1.2 percent to 15.2 percent at Red Bluff; and from 5.1 percent to 100 percent at Knights Landing.

Additionally, the severity of adverse effects to fall-run Chinook salmon juveniles under the PA thermal regime increases from upstream to downstream. This is evident by the increase in the degrees per day above the threshold for all water years combined from low levels (e.g., a degree or less) at Bend Bridge and Red Bluff to up to 7.4°F in June at Knights Landing.

Adult Immigration and Holding

Mean monthly water temperatures presented in the BA were evaluated in the Sacramento River at Keswick, Bend Bridge, and Red Bluff during the July through December adult immigration period for fall-run Chinook salmon. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) at these locations in all months and water year types in the period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.3.7-7, Table 5.C.7-8). The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F (0.9 percent to 1.1 percent), and would occur at Bend Bridge in below normal years during September and at Red Bluff in below normal years during August and above normal and below normal water years during September (Reclamation 2016).

Exceedance plots of monthly mean water temperatures were examined during each month and water year type throughout the adult immigration period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The curves for the PA generally match those of the NAA. For the cases with the highest increase in mean monthly water temperatures under the PA, temperatures under the PA would be consistently higher than those under the NAA by 0.5°F to 1°F across the range of temperatures (Figures 5.E-145 through 5.E-148).

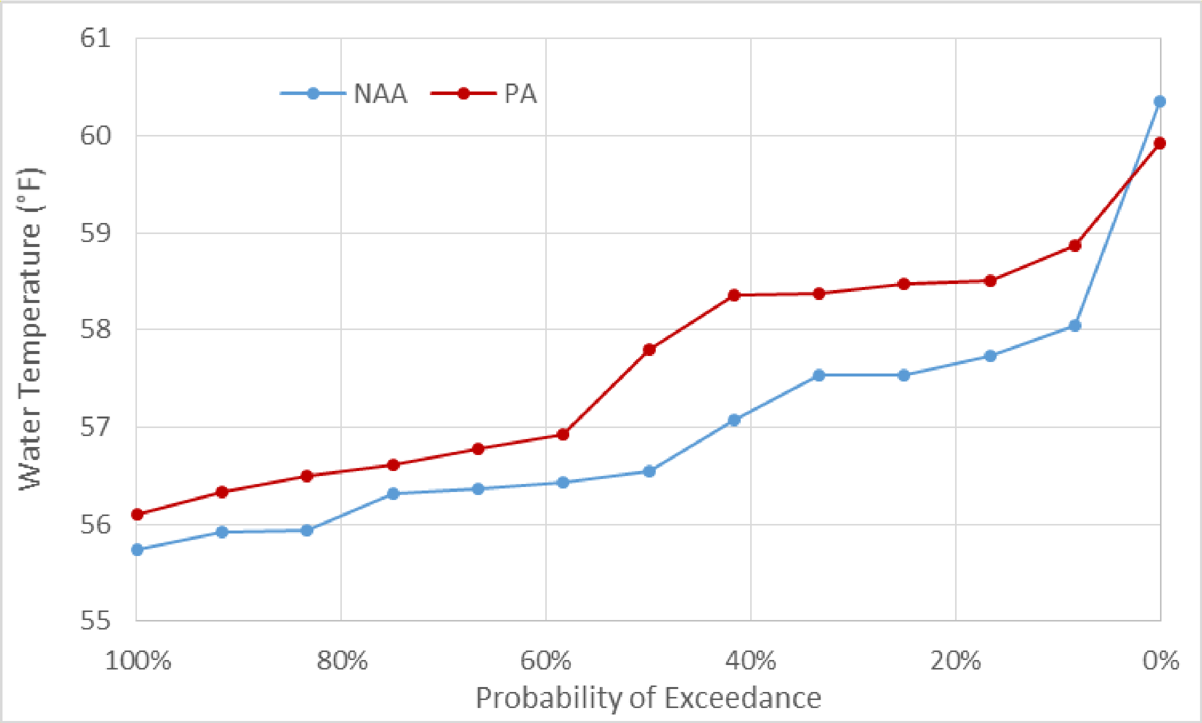

*Figure **Error! No text of specified style in document.**-18. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Above Normal Water Years*

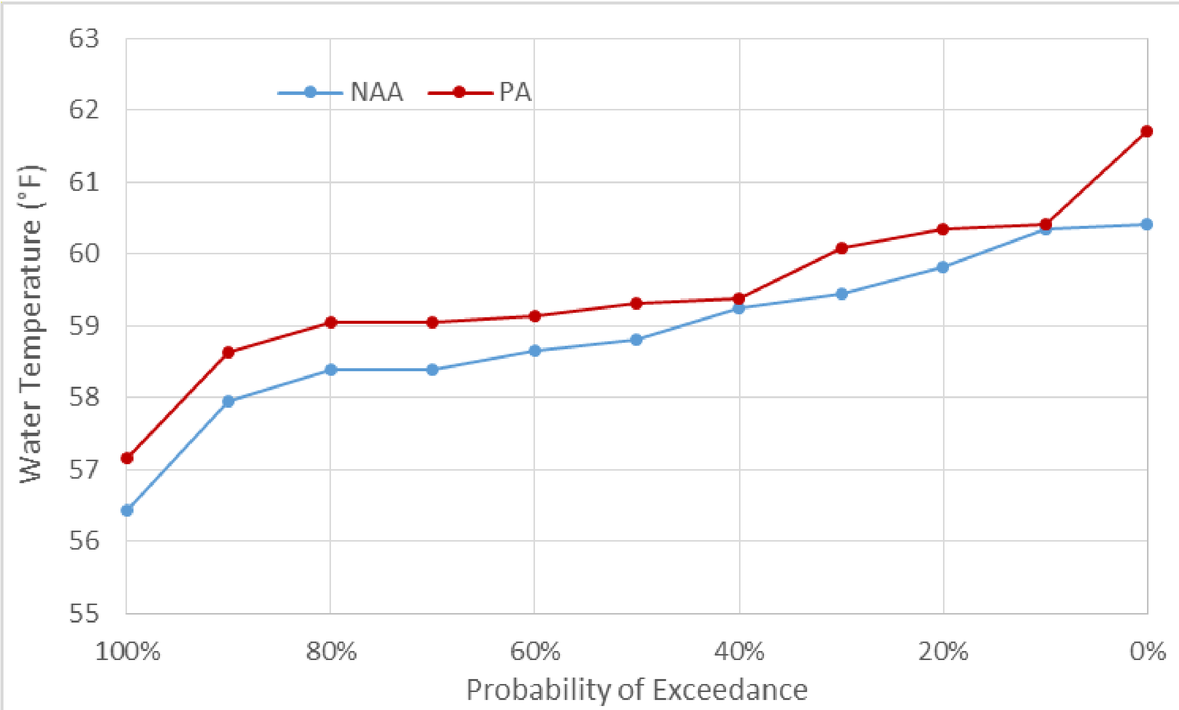

*Figure **Error! No text of specified style in document.**-19. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in September of Below Normal Water Years*

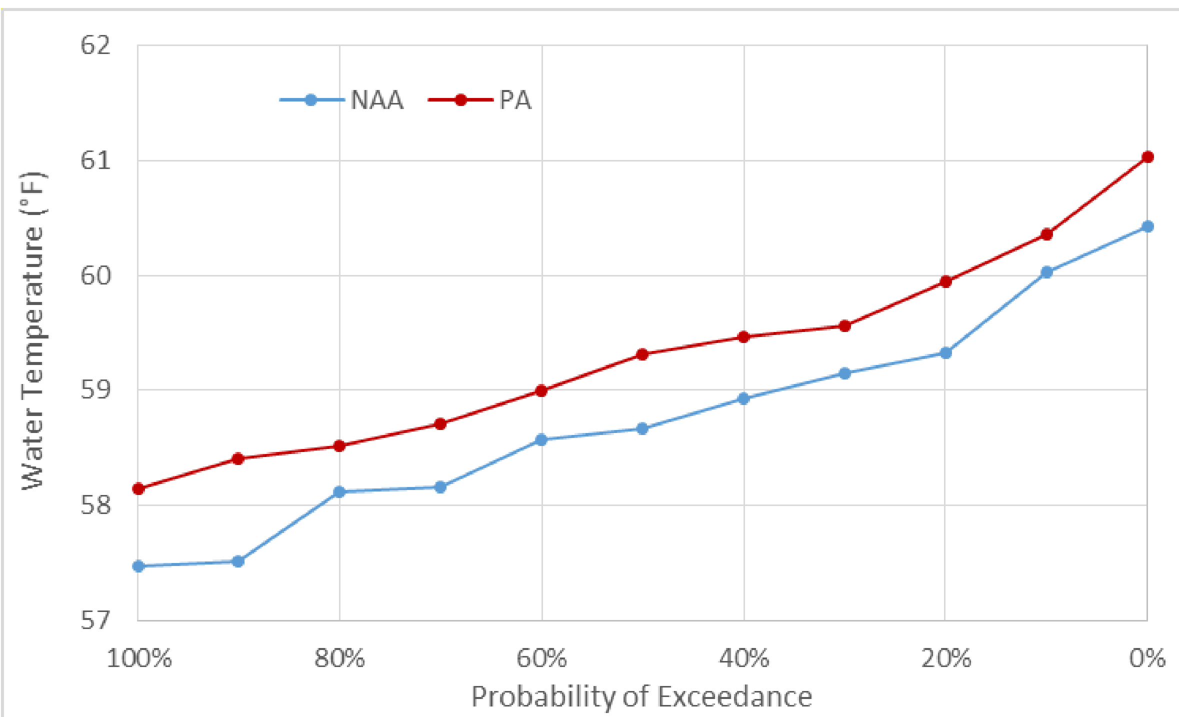

*Figure **Error! No text of specified style in document.**-20. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Below Normal Water Years*

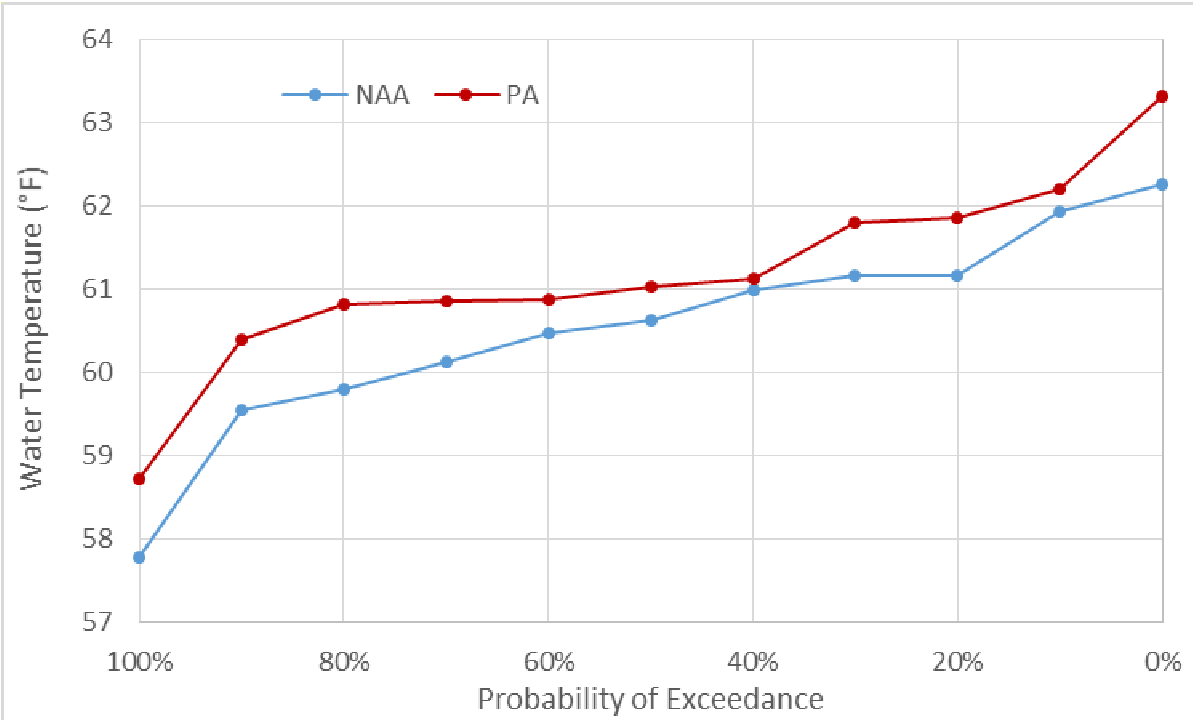

*Figure **Error! No text of specified style in document.**-21. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Below Normal Water Years*

The USEPA's 7DADM threshold value of 68°F was used to evaluate water temperature threshold exceedance during the fall-run Chinook salmon adult immigration life stage at Keswick, Bend Bridge, and Red Bluff. The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D- 4).

Results of the water temperature thresholds analysis show that adverse effects to Sacramento River fall-run Chinook salmon adults during upstream migration are unlikely to occur under the PA, except for during critical water years (Tables 5.E-12 through 5.E-14). The 68°F threshold for the protection of adult immigration is expected to be exceeded in critical water years under the PA at Keswick, Bend Bridge, and Red Bluff. The percentage of days that exceed the threshold in critical years ranges up to 2 percent at Keswick, 33 percent at Bend Bridge, and 55 percent at Red Bluff. The only other occurrences of the 68°F threshold being exceeded were at Red Bluff during below normal and dry years, but each of those were for less than 1 percent of the days during September. Overall, these temperature threshold analysis results indicate that adverse water temperature- related effects of the PA on fall-run Chinook salmon adult immigration in the Sacramento River would be limited to critical water years.

Table ***Error! No text of specified style in document.****-5. Delta Passage Model: Mokelumne River Fall-Run Chinook Salmon Mean Through-Delta (Total) Survival By Water Year Type*

WY	Total Survival		
	NAA	PA	PA vs. NAA
W	0.18	0.21	0.03 (16%)
AN	0.16	0.17	0.01 (6%)
BN	0.15	0.16	0.00 (3%)
D	0.15	0.16	0.01 (4%)
C	0.15	0.15	0.00 (1%)

Table ***Error! No text of specified style in document.****-6. Delta Passage Model: Late Fall-Run Chinook Salmon Mean Through-Delta (Total) Survival, Mainstem Sacramento River survival, and Proportion Using and Surviving Other Migration Routes*

WY	Total Survival			Mainstem Sacramento River Survival			Yolo Bypass					
							Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.29	0.27	-0.03 (-10%)	0.33	0.29	-0.04 (-13%)	0.05	0.06	0.00 (1%)	0.47	0.47	0.00 (0%)
AN	0.25	0.23	-0.02 (-9%)	0.29	0.26	-0.04 (-12%)	0.03	0.03	0.00 (0%)	0.47	0.47	0.00 (0%)
BN	0.25	0.21	-0.03 (-13%)	0.29	0.24	-0.05 (-16%)	0.02	0.02	0.00 (6%)	0.47	0.47	0.00 (0%)
D	0.21	0.20	-0.02 (-8%)	0.25	0.22	-0.03 (-11%)	0.02	0.02	0.00 (5%)	0.47	0.47	0.00 (0%)
C	0.19	0.18	-0.01 (-3%)	0.22	0.21	-0.01 (-5%)	0.02	0.02	0.00 (0%)	0.47	0.47	0.00 (0%)
WY	Sutter/Steamboat Sloughs						Interior Delta (Via Georgiana Slough/DCC)					
	Proportion Using Route			Survival			Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.29	0.27	-0.02 (-6%)	0.38	0.34	-0.04 (-10%)	0.30	0.32	0.02 (7%)	0.12	0.13	0.01 (11%)
AN	0.28	0.26	-0.02 (-6%)	0.34	0.31	-0.03 (-10%)	0.32	0.34	0.02 (6%)	0.11	0.12	0.01 (9%)
BN	0.28	0.26	-0.02 (-8%)	0.33	0.28	-0.04 (-13%)	0.32	0.35	0.03 (9%)	0.11	0.11	0.01 (9%)
D	0.26	0.24	-0.02 (-6%)	0.29	0.26	-0.03 (-9%)	0.35	0.37	0.02 (5%)	0.10	0.10	0.01 (8%)
C	0.24	0.23	-0.01 (-2%)	0.26	0.25	-0.01 (-4%)	0.38	0.38	0.00 (1%)	0.09	0.10	0.00 (5%)
Note: Survival in Sutter/Steamboat Sloughs and Interior Delta routes includes survival in the Sacramento River prior to entering the channel junctions.												

Table ***Error! No text of specified style in document.****-7. Mean Annual Fall-Run Chinook Salmon Weighted Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003), Divided into Each NDD Bypass Flow Level*

WY	Pulse protection flows			Level 1 bypass flows			Level 2 bypass flows			Level 3 bypass flows			Total		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.00	0.00	0.00 (0%)	0.00	0.00	0.00 (0%)	0.02	0.02	0.00 (1%)	0.76	0.76	0.00 (0%)	0.78	0.78	0.00 (0%)
AN	0.00	0.00	0.00 (0%)	0.00	0.00	0.00 (0%)	0.04	0.04	0.00 (0%)	0.60	0.59	-0.01 (-1%)	0.64	0.64	0.00 (1%)
BN	0.00	0.00	0.00 (0%)	0.21	0.21	0.00 (0%)	0.24	0.24	0.00 (1%)	0.10	0.09	0.00 (0%)	0.54	0.54	0.00 (0%)
D	0.00	0.00	0.00 (0%)	0.14	0.14	0.00 (2%)	0.28	0.29	0.00 (2%)	0.08	0.08	0.00 (1%)	0.50	0.51	0.00 (-1%)
C	0.00	0.00	0.00 (-1%)	0.34	0.33	0.00 (-1%)	0.07	0.07	0.00 (-1%)	0.00	0.00	0.00 (0%)	0.41	0.40	0.00 (-1%)

Water temperature-related impacts to Sacramento River fall-run Chinook salmon adult holding were evaluated with a thresholds analysis using the USEPA’s 7DADM threshold value of 61°F for the holding months of July and August at Keswick, Balls Ferry, and Red Bluff. At Keswick, adverse effects to holding fall-run Chinook salmon under the PA are expected only during September of critical water years, during which 32.5 percent of the days would exceed the 61° threshold. The occurrence of water temperature threshold exceedances increases slightly moving downstream to Balls Ferry where adverse effects to holding fall-run Chinook salmon are expected only during critical water years for 12.1 percent of the days in July and for 42.5 percent of the days in August. Thermal conditions for holding fall-run Chinook salmon become much worse at Red Bluff. There adverse effects would be expected in all water years in July and August with the 61°F threshold being exceeded up to 79 percent of the days in August of critical years.

2.5.1.2.1.5.1 American River

Spawning, Egg Incubation, and Alevin

Mean monthly water temperatures were evaluated during the October through January spawning, egg incubation, and alevin period for fall-run Chinook salmon in the American River reach between Hazel Avenue and Watt Avenue. Nearly all fall-run Chinook salmon spawning in the American River occurs from Watt Avenue upstream(BA Table 5.D.1-4 in Appendix 5D Attachment 1). Overall, the PA would change mean water temperatures very little (less than 1°F, or less than one percent) throughout the reach in all months and water year types of the period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-15). The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4 percent, and would occur at both Hazel Avenue and Watt Avenue during above normal water years during October. This greatest increase would occur outside of the peak spawning, egg incubation, and alevin period (November and December).

Table ***Error! No text of specified style in document.****-8. American River at Hazel Ave, Monthly Temperature*

Statistic	Monthly Temperature (Deg-F)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	66.3	66.1	-0.2	0%	58.2	58.0	-0.2	0%	53.3	52.7	-0.6	-1%	47.9	48.1	0.1	0%	48.4	48.7	0.2	0%	52.3	52.4	0.0	0%
20%	65.4	65.1	-0.3	0%	57.9	57.8	-0.1	0%	51.9	51.7	-0.2	0%	47.3	47.3	0.0	0%	47.8	47.8	0.0	0%	51.6	51.8	0.2	0%
30%	64.4	64.2	-0.2	0%	57.7	57.6	-0.1	0%	51.2	51.1	0.0	0%	46.9	47.0	0.1	0%	47.4	47.5	0.1	0%	50.6	50.6	0.0	0%
40%	63.8	63.4	-0.3	-1%	57.3	57.3	0.0	0%	50.7	50.7	0.0	0%	46.8	46.8	0.0	0%	46.9	46.9	0.0	0%	49.8	49.8	-0.1	0%
50%	63.3	63.1	-0.1	0%	57.1	57.0	-0.1	0%	50.3	50.1	-0.2	0%	46.1	46.2	0.1	0%	46.6	46.5	-0.1	0%	49.4	49.4	0.0	0%
60%	63.1	63.0	-0.1	0%	56.9	56.8	-0.1	0%	49.0	49.5	0.4	1%	45.8	45.8	0.0	0%	46.3	46.2	-0.1	0%	49.0	49.0	0.0	0%
70%	62.8	62.8	0.0	0%	56.7	56.6	-0.1	0%	48.5	48.6	0.2	0%	45.3	45.4	0.0	0%	46.0	46.0	0.0	0%	48.7	48.6	-0.1	0%
80%	62.7	62.7	0.0	0%	56.1	56.2	0.0	0%	48.1	48.3	0.2	0%	44.9	45.0	0.1	0%	45.8	45.7	0.0	0%	48.3	48.3	0.0	0%
90%	59.2	59.3	0.2	0%	55.7	55.4	-0.3	-1%	46.9	46.9	0.0	0%	44.5	44.4	-0.1	0%	45.4	45.4	0.0	0%	48.0	48.0	0.0	0%
Long Term Full Simulation Period[b]	63.4	63.3	-0.1	0%	57.0	56.9	-0.1	0%	50.0	50.0	-0.1	0%	46.2	46.2	0.0	0%	46.8	46.8	0.0	0%	49.9	49.8	0.0	0%
Water Year Types[c]																								
Wet (32%)	61.6	61.6	0.0	0%	57.0	56.9	-0.1	0%	50.7	50.8	0.0	0%	46.5	46.5	0.0	0%	46.0	45.9	-0.1	0%	48.6	48.5	-0.1	0%
Above Normal (16%)	63.1	63.3	0.2	0%	56.7	56.7	0.0	0%	50.0	50.1	0.1	0%	46.4	46.6	0.1	0%	46.5	46.5	0.0	0%	49.0	48.9	0.0	0%
Below Normal (13%)	63.8	63.8	-0.1	0%	57.3	57.0	-0.3	0%	50.4	50.1	-0.3	-1%	46.2	46.0	-0.2	0%	46.7	46.7	0.0	0%	50.0	50.0	0.0	0%
Dry (24%)	64.4	64.1	-0.3	0%	56.9	56.7	-0.3	0%	49.5	49.3	-0.2	0%	46.1	46.0	-0.1	0%	47.3	47.3	0.0	0%	50.6	50.6	0.0	0%
Critical (15%)	65.6	65.2	-0.4	-1%	57.5	57.4	-0.1	0%	49.0	49.1	0.1	0%	45.6	45.6	0.0	0%	48.0	48.0	0.0	0%	52.3	52.3	0.0	0%

Statistic	Monthly Temperature (Deg-F)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	57.8	57.7	-0.1	0%	63.1	63.0	-0.1	0%	67.5	67.0	-0.5	-1%	68.9	68.7	-0.3	0%	67.2	67.3	0.1	0%	68.4	68.5	0.1	0%
20%	57.0	56.8	-0.2	0%	61.7	61.8	0.0	0%	65.7	65.8	0.1	0%	66.8	67.0	0.2	0%	66.7	66.8	0.1	0%	67.6	67.7	0.1	0%
30%	56.0	56.1	0.1	0%	60.8	60.6	-0.2	0%	64.5	64.7	0.2	0%	65.3	65.2	-0.1	0%	65.7	65.7	0.0	0%	66.4	66.6	0.2	0%
40%	55.3	55.3	0.0	0%	59.6	59.5	-0.1	0%	63.0	63.0	0.1	0%	64.9	64.7	-0.2	0%	65.0	65.1	0.1	0%	65.8	65.8	0.0	0%
50%	54.5	54.5	0.0	0%	58.3	58.3	0.0	0%	61.7	62.3	0.7	1%	64.6	64.5	-0.1	0%	64.3	64.3	0.0	0%	65.2	65.3	0.0	0%
60%	54.0	54.0	0.0	0%	57.8	57.8	0.0	0%	60.7	61.0	0.3	1%	64.5	64.2	-0.3	-1%	64.0	63.9	-0.1	0%	64.9	64.9	0.0	0%
70%	53.4	53.4	0.0	0%	57.0	57.0	0.0	0%	59.7	59.9	0.2	0%	64.4	63.8	-0.6	-1%	63.4	63.4	0.0	0%	64.3	64.3	0.0	0%
80%	52.4	52.4	0.0	0%	56.5	56.5	0.0	0%	59.3	59.3	0.0	0%	63.8	63.6	-0.2	0%	63.1	62.8	-0.2	0%	64.1	64.0	0.0	0%
90%	51.9	51.7	-0.2	0%	54.9	54.9	0.1	0%	59.0	59.0	0.0	0%	63.5	63.4	-0.1	0%	62.2	62.3	0.0	0%	63.1	63.1	0.0	0%
Long Term Full Simulation Period[b]	54.7	54.7	-0.1	0%	59.0	58.9	-0.1	0%	62.5	62.4	0.0	0%	65.3	65.2	-0.1	0%	64.6	64.7	0.1	0%	65.5	65.5	0.0	0%
Water Year Types[c]																								
Wet (32%)	52.8	52.7	-0.1	0%	56.6	56.6	0.0	0%	59.9	59.8	-0.1	0%	63.8	63.8	-0.1	0%	62.8	62.9	0.1	0%	63.8	63.7	-0.1	0%
Above Normal (16%)	54.2	54.2	0.0	0%	58.3	58.3	0.0	0%	61.8	62.1	0.4	1%	64.5	64.2	-0.3	0%	64.1	64.1	-0.1	0%	64.9	65.0	0.1	0%
Below Normal (13%)	56.1	56.1	0.0	0%	60.2	60.1	0.0	0%	63.7	63.0	-0.7	-1%	65.1	64.9	-0.2	0%	65.2	64.9	-0.3	0%	65.6	65.8	0.3	0%
Dry (24%)	55.5	55.3	-0.1	0%	60.2	60.0	-0.2	0%	63.7	63.9	0.1	0%	65.9	65.8	-0.1	0%	65.5	65.6	0.1	0%	66.4	66.5	0.1	0%
Critical (15%)	57.1	57.0	-0.1	0%	62.0	62.0	0.0	0%	65.6	65.6	0.0	0%	68.8	68.9	0.1	0%	66.8	67.8	0.9	1%	68.1	67.9	-0.2	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year.
b Based on the 82-year simulation period.
c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.
d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

Table ***Error! No text of specified style in document.****-9. American River at Watt Ave, Monthly Temperature*

Statistic	Monthly Temperature (Deg-F)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	67.2	66.9	-0.3	0%	58.3	58.3	0.0	0%	52.5	52.1	-0.5	-1%	48.3	48.5	0.1	0%	50.0	50.1	0.1	0%	56.2	56.3	0.1	0%
20%	65.7	65.6	-0.2	0%	58.0	57.9	-0.1	0%	51.6	51.3	-0.3	-1%	47.8	47.8	0.0	0%	49.5	49.5	0.0	0%	54.7	55.0	0.3	0%
30%	64.9	64.8	-0.1	0%	57.6	57.5	-0.1	0%	50.8	50.8	0.1	0%	47.4	47.5	0.1	0%	48.6	48.6	0.0	0%	52.9	52.9	0.0	0%
40%	64.5	64.5	0.0	0%	57.3	57.3	0.0	0%	50.5	50.4	0.0	0%	47.1	47.2	0.0	0%	48.3	48.2	-0.1	0%	51.9	51.9	0.0	0%
50%	64.1	64.0	-0.1	0%	57.1	57.1	0.0	0%	þ0.0	49.9	-0.1	0%	46.7	46.7	0.0	0%	47.8	47.7	-0.1	0%	51.3	51.3	0.0	0%
60%	63.8	63.6	-0.2	0%	56.8	56.7	-0.1	0%	49.0	49.5	0.5	1%	46.3	46.3	0.0	0%	47.2	47.3	0.1	0%	50.4	50.4	0.0	0%
70%	63.3	63.3	0.0	0%	56.5	56.4	-0.1	0%	48.5	48.7	0.1	0%	45.7	45.7	-0.1	0%	46.9	46.8	-0.1	0%	50.0	49.9	-0.1	0%
80%	63.1	63.0	-0.1	0%	56.1	56.1	0.0	0%	48.0	48.3	0.2	0%	45.2	45.3	0.1	0%	46.5	46.4	0.0	0%	49.7	49.6	0.0	0%
90%	61.0	61.3	0.3	1%	55.8	55.5	-0.3	-1%	47.3	47.1	-0.2	0%	44.9	44.7	-0.2	-1%	46.1	45.9	-0.2	0%	49.2	49.0	-0.2	0%
Long Term Full Simulation Period[b]	64.1	64.1	-0.1	0%	57.0	56.9	-0.1	0%	49.8	49.8	0.0	0%	46.7	46.6	0.0	0%	48.0	48.0	-0.1	0%	52.0	51.9	0.0	0%
Water Year Types[c]																								
Wet (32%)	62.5	62.6	0.1	0%	57.0	56.9	-0.1	0%	50.5	50.5	0.0	0%	46.8	46.8	0.0	0%	46.7	46.6	-0.1	0%	49.9	49.8	-0.1	0%
Above Normal (16%)	63.8	63.9	0.2	0%	56.6	56.6	0.0	0%	49.8	49.9	0.1	0%	46.8	46.9	0.1	0%	47.5	47.4	-0.1	0%	50.4	50.4	0.0	0%
Below Normal (13%)	64.4	64.3	0.0	0%	57.2	57.0	-0.2	0%	50.0	49.8	-0.2	0%	46.5	46.3	-0.1	0%	47.8	47.7	-0.1	0%	52.5	52.5	0.0	0%
Dry (24%)	65.0	64.8	-0.2	0%	56.9	56.7	-0.2	0%	49.4	49.2	-0.2	0%	46.6	46.4	-0.1	0%	48.8	48.8	0.0	0%	53.2	53.1	-0.1	0%
Critical (15%)	66.4	66.0	-0.4	-1%	57.5	57.5	0.0	0%	49.1	49.1	0.1	0%	46.6	46.5	0.0	0%	50.5	50.5	0.0	0%	55.5	55.7	0.2	0%

Statistic	Monthly Temperature (Deg-F)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	62.7	62.3	-0.4	-1%	67.6	67.9	0.2	0%	72.8	71.5	-1.3	-2%	73.2	73.9	0.8	1%	73.0	73.5	0.5	1%	71.3	72.0	0.6	1%
20%	60.2	60.4	0.2	0%	66.5	66.1	-0.4	-1%	70.1	69.2	-1.0	-1%	69.8	70.1	0.2	0%	71.8	71.8	0.1	0%	70.3	70.5	0.2	0%
30%	59.0	59.1	0.1	0%	65.3	65.2	-0.1	0%	68.7	68.0	-0.7	-1%	68.7	69.0	0.3	0%	69.7	69.7	0.0	0%	68.9	69.2	0.4	1%
40%	57.7	57.6	-0.2	0%	63.8	63.8	0.0	0%	66.7	66.6	-0.1	0%	68.2	68.1	-0.2	0%	69.2	69.3	0.1	0%	68.5	68.3	-0.2	0%
50%	57.0	57.0	0.0	0%	62.3	62.3	0.1	0%	66.0	65.8	-0.2	0%	67.8	67.6	-0.3	0%	68.6	68.7	0.1	0%	67.7	67.8	0.1	0%
60%	56.4	56.5	0.0	0%	61.0	61.0	0.0	0%	64.8	64.3	-0.5	-1%	67.6	67.4	-0.2	0%	68.0	68.1	0.1	0%	67.2	67.2	0.0	0%
70%	55.0	55.0	0.0	0%	59.7	59.8	0.0	0%	63.7	63.7	0.0	0%	67.4	67.1	-0.2	0%	67.7	67.7	0.0	0%	66.4	66.6	0.1	0%
80%	54.2	54.2	0.0	0%	59.1	59.1	0.0	0%	62.9	62.9	0.0	0%	67.0	66.7	-0.3	0%	66.8	66.7	-0.1	0%	65.9	66.0	0.0	0%
90%	53.4	53.0	-0.4	-1%	57.1	57.0	-0.1	0%	61.9	62.0	0.1	0%	66.5	66.4	-0.1	0%	65.7	65.6	-0.1	0%	65.0	65.0	0.0	0%
Long Term Full Simulation Period[b]	57.4	57.4	0.0	0%	62.6	62.5	-0.1	0%	66.5	66.1	-0.3	0%	68.9	68.9	0.0	0%	69.1	69.2	0.2	0%	68.0	68.1	0.1	0%
Water Year Types[c]																								
Wet (32%)	54.7	54.6	-0.1	0%	59.3	59.3	0.0	0%	63.4	63.1	-0.3	0%	67.4	67.2	-0.2	0%	66.9	66.9	0.1	0%	65.7	65.7	0.0	0%
Above Normal (16%)	56.3	56.4	0.0	0%	61.9	62.0	0.0	0%	65.9	65.8	-0.1	0%	67.2	67.2	0.0	0%	68.2	68.1	-0.1	0%	67.1	67.3	0.2	0%
Below Normal (13%)	59.1	59.1	0.0	0%	64.0	63.9	-0.1	0%	67.9	66.6	-1.3	-2%	67.9	68.1	0.2	0%	70.1	69.5	-0.5	-1%	68.7	68.9	0.2	0%
Dry (24%)	58.5	58.4	-0.1	0%	64.2	64.1	-0.2	0%	67.8	67.4	-0.4	-1%	69.5	69.5	0.0	0%	70.3	70.6	0.3	0%	69.3	69.4	0.1	0%
Critical (15%)	61.4	61.4	0.0	0%	66.6	66.6	0.0	0%	70.2	70.6	0.4	1%	74.2	74.2	0.0	0%	72.0	73.0	1.0	1%	71.5	71.5	0.0	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year.
b Based on the 82-year simulation period.
c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.
d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

The exceedance of temperature thresholds in the American River presented in the BA in Appendix, *Methods*, Table 5.E-22 by modeled daily water temperatures were evaluated based on thresholds identified from the literature and the USEPA's temperature water quality guidance (U.S. Environmental Protection Agency 2003). For spawning, egg incubation, and alevin presence, the threshold used was from the USEPA's 7-day average daily maximum (7DADM) value of 55.4°F, converted by month to function with daily model outputs for each month separately (BA Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of*

Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale, Section 5.D.2.1, *Water Temperature Analysis Methods,* Table 5.D-4).

The water temperature thresholds analysis presented in the BA provides an indication that water temperatures in the American River under the PA are expected to have an adverse effect on fall-run Chinook salmon spawning, egg incubation, and alevin development. As pointed out in the BA (pages 5.E-283), the differences in the percent of days above the spawning, egg, and alevin water temperature threshold (i.e., 55.4 7DADM) between the NAA and the PA would be minimal across months, locations, and water year types (BA Attachment 5.E.1, *Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results,* Table 5.E.1-32 through 5.E.1-33). At both Hazel Avenue and Watt Avenue, there would be no months or water year types in which there would be 5 percent more days under the PA compared to the NAA on which temperatures would exceed the threshold or a more-than-0.5°F difference in the magnitude of average daily exceedance.

However, adverse effects to fall-run Chinook salmon eggs under the PA are expected to occur in every single year regardless of water year type. That is because water temperatures are expected to exceed 55.4F 7DADM for a long duration during the peak of spawning and egg incubation over the full range of hydrologic conditions. For example, the water temperature threshold analysis shows that water temperatures at Hazel Avenue under the PA during the peak spawning month of November will exceed the temperature threshold for at least 80 percent of the days in critical water years ranging up to 91 percent of the days in wet water years (Table 5.E.1-32). The longer the duration of exposure to water temperatures that are warmer than the threshold, the greater the severity of adverse effects. Conditions worsen further downstream at near Watt Avenue, with PA water temperatures in November exceeding the egg and alevin threshold (i.e., 55.4F 7DADM) for 83 percent to 93 percent of the days across all water year types (Table 5.E.1-33). Egg and alevin mortality above natural levels (i.e., little to no thermal stress) is expected under such a thermal regime, clearly resulting in adverse effects to fall-run Chinook salmon in the American River.

*Table **Error! No text of specified style in document.**-10. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Spawning and Embryo Incubation, American River at Hazel Avenue, 55.4°F 7DADM[1]*

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Oct	W	100.0	100.0	0.0	5,499	5,518	19	6.82	6.85	0.02
	AN	100.0	100.0	0.0	3,083	3,167	84	8.29	8.51	0.23
	BN	100.0	100.0	0.0	3,078	3,054	-24	9.03	8.96	-0.07
	D	100.0	100.0	0.0	5,973	5,785	-188	9.63	9.33	-0.30
	C	100.0	100.0	0.0	4,031	3,871	-160	10.84	10.41	-0.43
	All	100.0	100.0	0.0	21,664	21,395	-269	8.63	8.52	-0.11
Nov	W	89.9	91.4	1.5	2,006	1,957	-49	2.86	2.74	-0.12
	AN	84.4	84.2	-0.3	862	852	-10	2.84	2.81	-0.02
	BN	86.7	83.0	-3.6	951	861	-90	3.33	3.14	-0.18
	D	83.0	80.5	-2.5	1,624	1,528	-96	3.26	3.16	-0.10
	C	80.6	80.3	-0.3	1,153	1,136	-17	3.98	3.93	-0.05
	All	85.6	84.9	-0.7	6,596	6,334	-262	3.17	3.07	-0.10
Dec	W	15.0	15.6	0.6	243	229	-14	2.01	1.82	-0.19
	AN	6.7	6.5	-0.3	33	31	-2	1.32	1.29	-0.03
	BN	9.1	5.0	-4.1	35	21	-14	1.13	1.24	0.11
	D	1.9	2.4	0.5	10	9	-1	0.83	0.60	-0.23
	C	5.1	6.2	1.1	26	27	1	1.37	1.17	-0.19
	All	8.3	8.2	-0.1	347	317	-30	1.67	1.55	-0.12
Jan	W	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	AN	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	BN	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	D	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	C	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	All	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA

[1]7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table ***Error! No text of specified style in document.****-11. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Spawning and Embryo Incubation, American River at Watt Avenue, 55.4°F 7DADM*[1]

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Oct	W	100.0	100.0	0.0	7,326	7,391	65	9.09	9.17	0.08
	AN	100.0	100.0	0.0	3,858	3,925	67	10.37	10.55	0.18
	BN	100.0	100.0	0.0	3,752	3,737	-15	11.00	10.96	-0.04
	D	100.0	100.0	0.0	7,196	7,060	-136	11.61	11.39	-0.22
	C	100.0	100.0	0.0	4,837	4,699	-138	13.00	12.63	-0.37
	All	100.0	100.0	0.0	26,969	26,812	-157	10.74	10.68	-0.06
Nov	W	92.1	93.2	1.2	2,648	2,602	-46	3.69	3.58	-0.11
	AN	87.2	88.9	1.7	1,102	1,092	-10	3.51	3.41	-0.10
	BN	88.8	87.6	-1.2	1,195	1,124	-71	4.08	3.89	-0.19
	D	86.3	83.2	-3.2	2,050	1,957	-93	3.96	3.92	-0.04
	C	84.7	84.4	-0.3	1,432	1,428	-4	4.70	4.70	0.00
	All	88.4	88.0	-0.4	8,427	8,203	-224	3.92	3.83	-0.09
Dec	W	15.0	15.6	0.6	224	213	-11	1.85	1.69	-0.16
	AN	6.5	6.5	0.0	32	30	-2	1.33	1.25	-0.08
	BN	8.8	5.0	-3.8	31	16	-15	1.03	0.94	-0.09
	D	2.4	2.4	0.0	15	13	-2	1.00	0.87	-0.13
	C	5.1	6.5	1.3	16	17	1	0.84	0.71	-0.13
	All	8.3	8.2	-0.1	318	289	-29	1.52	1.40	-0.12
Jan	W	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	AN	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	BN	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	D	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	C	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	All	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA

[1]7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Fry, Juvenile Rearing and Outmigration

Mean monthly water temperatures were evaluated during the December through June juvenile rearing and emigration period for fall-run Chinook salmon in the American River between Hazel Avenue and Watt Avenue, with a peak period during January and February. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) throughout the fry and juvenile rearing reach in all months and water year types (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-14, Table 5.C.7-15). The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4 percent, and would occur at Watt Avenue in critical water years during March, outside the peak period of rearing.

As presented in the BA, the water temperature thresholds analysis for fall-run Chinook salmon juvenile rearing and emigration have been combined and the period of December through June was evaluated. The threshold used was from the USEPA's 7DADM value of 61°F for the core juvenile rearing reach represented by Hazel Avenue and 64°F for the non-core juvenile rearing reach represented by Watt Avenue.

Results of the water temperature thresholds analysis indicate that an adverse effect to fall-run Chinook salmon juveniles in the American River is expected under the PA's thermal regime (Tables 5.E.1-34 and 5.E.1-35). The general pattern is that daily occurrences of threshold exceedances under the PA increase as fish move downstream from Hazel Avenue and as the season progresses from April to May, and although the tabular results for the threshold analysis erroneously do not include June, it is safely assumed that the trend of increasing threshold exceedances continues through June because the mean monthly water temperature results show a warming trend from April through June at both the Hazel and Watt Avenue locations. As such, the frequency of adverse effects to fall-run Chinook salmon juveniles are expected to increase from Hazel Avenue downstream and from month to month during the April through June period. The mean percentage of days for all water years combined where April and May water temperatures under the PA are expected to exceed the 7DADM thresholds (61°F for core at Hazel, 64°F for non-core at Watt) ranges from 3 percent up to 30 percent at Hazel Avenue and from 12 percent to 51 percent at Watt Avenue.

Additionally, the severity of adverse effects to fall-run Chinook salmon juveniles under the PA thermal regime increases from upstream to downstream. This is evident by the increase in the degrees per day above the thresholds for all water years combined from Hazel Avenue to Watt Avenue during both May and June. The water temperature thresholds analysis results indicate that adverse effects to juvenile fall-run Chinook salmon are expected in April, May, and June in all water years with implementation of the PA.

*Table **Error! No text of specified style in document.**-12. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Juvenile Rearing and Emigration, American River at River at Hazel Avenue, 61°F 7DADM*

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Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	10.6	10.9	0.3	28	28	0	0.80	0.78	-0.02
	D	2.2	1.7	-0.5	11	5	-6	0.85	0.50	-0.35
	C	7.8	7.5	-0.3	18	29	11	0.64	1.07	0.43
	All	3.1	3.0	-0.1	57	62	5	0.75	0.85	0.10
May	W	7.6	7.6	0.0	145	143	-2	2.38	2.34	-0.03
	AN	9.7	9.7	0.0	46	46	0	1.18	1.18	0
	BN	43.4	42.5	-0.9	441	442	1	2.98	3.05	0.07
	D	43.5	42.6	-1.0	776	659	-117	2.87	2.50	-0.38
	C	64.2	64.8	0.5	808	834	26	3.38	3.46	0.08
	All	29.8	29.5	-0.3	2,216	2,124	-92	2.93	2.83	-0.10

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table ***Error! No text of specified style in document.****-13. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Juvenile Rearing and Emigration, American River at Watt Avenue, 64°F 7DADM*

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.6	0.6	0.0	5	5	0	1.00	1.00	0
	AN	0.3	0.3	0.0	1	1	0	1.00	1.00	0
	BN	22.1	23.3	1.2	180	185	5	2.47	2.40	-0.06
	D	14.0	13.2	-0.8	179	141	-38	2.13	1.78	-0.35
	C	36.9	36.7	-0.3	367	378	11	2.76	2.86	0.10
	All	12.0	12.0	-0.1	732	710	-22	2.47	2.41	-0.06
May	W	17.7	18.0	0.2	461	461	0	3.22	3.18	-0.04
	AN	48.6	48.9	0.2	402	404	2	2.05	2.05	0
	BN	62.8	61.9	-0.9	996	957	-39	4.65	4.54	-0.12
	D	68.9	68.7	-0.2	1,856	1,761	-95	4.35	4.13	-0.21
	C	84.9	84.7	-0.3	1,832	1,851	19	5.80	5.88	0.08
	All	51.0	50.9	-0.1	5,547	5,434	-113	4.28	4.20	-0.08

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Adult Immigration

As with the other life stage periods, water temperatures expected to occur during the September through December period for fall-run Chinook salmon adult immigration under the PA will be similar to those under the NAA. Mean monthly water temperatures were evaluated in the American River at Hazel Avenue and Watt Avenue during the September through December adult immigration period for fall-run Chinook salmon, with a peak of September and October. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately one percent) at these locations in all months and water year types in the period (BA Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-14, Table 5.C.7-15). The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.3°F (0.4 percent), and would occur at Hazel Avenue during September of below normal water years, within the peak period of adult immigration.

As presented in the BA, the USEPA's 7DADM threshold value of 68°F was used to evaluate water temperature threshold exceedance during the fall-run Chinook salmon adult immigration life stage at Hazel Avenue and Watt Avenue. The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.2.1, *Water Temperature Analysis Methods,* Table 5.D-4).

Results of the water temperature thresholds analysis for adult fall-run Chinook salmon immigration are presented in Tables 5.E-36 and 5.E-37. At Hazel Avenue, there would be one month and water year type (below normal water years during September) in which there would be a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA (8.8 percent), but there would not be a more-than-0.5°F difference in the magnitude of average daily exceedance. At Watt Avenue, there would be no months or water types in which there would be a more-than-5 percent increase in the percent of total days exceeding the threshold under the PA relative to the NAA or a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that any adverse water temperature- related effects of the PA on adult fall-run Chinook salmon immigration would be similar to those of the NAA.

However, adverse effects to fall-run Chinook salmon eggs under the PA are expected to occur in every single year regardless of water year type. That is because water temperatures are expected to exceed the 68°F 7DADM threshold for a long duration during the peak of adult immigration over the full range of hydrologic conditions. For example, the water temperature threshold analysis shows that water temperatures at Watt Avenue under the PA during the peak adult immigration month of October will exceed the temperature threshold for at least 5 percent of the days in critical water years ranging up to 55 percent of the days in wet water years (Table 5.E.1-37). The longer the duration of exposure to water temperatures that are warmer than the threshold, the greater the severity of adverse effects. Conditions worsen for any adult fall-run Chinook salmon immigrating into the American River in September, with PA water temperatures at Watt Avenue exceeding the water temperature threshold (i.e., 68°F 7DADM) for 54 percent of the days in wet water years up to 100 percent of the days in critical water years (Table 5.E.1-37). The extended duration of exposure to water temperatures above the threshold is expected to increase the probability of pre-spawn mortality of adults and reduce in vitro egg viability, clearly resulting in adverse effects to fall-run Chinook salmon in the American River.

Table ***Error! No text of specified style in document.****-14. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Adult Immigration, American River at Hazel Avenue, 68°F 7DADM[1]*

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Sep	W	2.9	3.3	0.4	13	11	-2	0.57	0.42	-0.14
	AN	0.0	1.5	1.5	0	1	1	NA	0.17	NA
	BN	3.3	12.1	8.8	15	35	20	1.36	0.88	-0.49
	D	28.3	31.2	2.8	147	192	45	0.86	1.03	0.16
	C	76.7	72.5	-4.2	392	394	2	1.42	1.51	0.09
	All	19.5	21.1	1.6	567	633	66	1.18	1.22	0.04
Oct	W	0.0	0.2	0.2	0	0	0	NA	0	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	2.6	0.9	-1.8	4	1	-3	0.44	0.33	-0.11
	D	4.7	5.2	0.5	25	25	0	0.86	0.78	-0.08
	C	22.6	20.7	-1.9	42	30	-12	0.50	0.39	-0.11
	All	4.9	4.5	-0.3	71	56	-15	0.58	0.49	-0.09
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table ***Error! No text of specified style in document.****-15. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Adult Immigration, American River at Watt Avenue, 68°F 7DADM*[1]

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Sep	W	55.9	54.1	-1.8	619	634	15	1.42	1.50	0.08
	AN	91.5	96.4	4.9	636	708	72	1.78	1.88	0.10
	BN	97.3	96.4	-0.9	1,079	1,134	55	3.36	3.57	0.20
	D	98.7	98.5	-0.2	2,282	2,367	85	3.85	4.01	0.15
	C	97.2	99.7	2.5	2,157	2,159	2	6.16	6.01	-0.15
	All	83.6	84.0	0.4	6,773	7,002	229	3.29	3.39	0.09
Oct	W	3.7	4.5	0.7	30	37	7	1.00	1.03	0.03
	AN	9.7	13.7	4.0	25	33	8	0.69	0.65	-0.05
	BN	22.6	22.9	0.3	98	97	-1	1.27	1.24	-0.03
	D	31.9	31.3	-0.6	308	307	-1	1.56	1.58	0.03
	C	62.1	55.4	-6.7	521	436	-85	2.26	2.12	-0.14
	All	22.8	22.5	-0.3	982	910	-72	1.72	1.61	-0.11
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1]7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

2.5.1.2.2 Redd Dewatering

Redd dewatering is a risk to incubating salmonid eggs and alevin. Water must move through a redd at a swift enough velocity to sweep out fine sediment and metabolic waste. Otherwise, incubating eggs do not receive sufficiently clean, oxygenated water to support proper development. Therefore, salmonid redd dewatering can occur when water levels decrease after redd construction and spawning, exposing buried and otherwise submerged eggs or alevins to air.

Dewatering can affect eggs and alevins in multiple ways. Dewatered gravel must maintain near 100 percent humidity for eggs and embryos to survive over successive days. While inadequate moisture and dissolved oxygen have been shown to affect the survival of all egg stages, the post-hatch eleuthroembryo and alevin stage are most sensitive to redd dewatering and usually die within 24 hours (Becker and Nietzel, 1983). Studies have shown that dewatering can impair egg and alevin development and cause direct mortality due to desiccation, insufficient oxygen levels, waste metabolite toxicity, and thermal stress (Reiser and White 1983, Becker and Neitzel 1985).

Redd dewatering can be a major source of salmonid population mortality in any water year type. Salmonid redds require cool, oxygenated, low turbidity water for approximately three to four months to complete the egg-alevin life stages. Therefore, the water level conditions at spawning should be maintained for at least three months after eggs are deposited in the gravel. Any reduction in water level within that period introduces a dewatering risk, almost regardless of the spawning condition. Because instream flows on the Sacramento and American rivers are primarily dependent on reservoir releases, the risk of redd dewatering can in large part be controlled through water operations.

Dewatering of green sturgeon spawning areas is not a concern because of the different spawning habitat that these fish use in contrast to the type of habitat conditions necessary for salmonid spawning. Green sturgeon spawning primarily occurs in cool sections of the upper mainstem Sacramento River in deep pools containing small to medium sized gravel, cobble or boulder substrate (Klimley et al. 2015; Poytress et al. 2015). Sturgeon eggs primarily adhere to gravel or cobble substrates, or settle into crevices (Moyle et al. 1995; Van Eenennaam et al. 2001; Poytress et al. 2015) where they incubate for a period of seven to nine days and remain near the hatching area for 18 to 35 days prior to dispersing (Van Eenennaam et al. 2001; Deng et al. 2002; Poytress et al. 2015). Larval activity is primarily nocturnal, with peaks in migration between dusk and dawn (Poytress et al. 2015). Larvae utilize benthic structure (Van Eenennaam et al. 2001; Deng et al. 2002; Kynard et al. 2005) and seek refuge within crevices, but will forage over hard surfaces (Nguyn and Crocker 2006).

2.5.1.2.2.1 Winter-run Exposure and Risk

Sacramento River winter-run Chinook salmon eggs and alevins are most vulnerable to dewatering during periods of significant river flow fluctuation in the Sacramento River which can occur in August, late in the incubation period (Vogel and Marine 1991). Essentially all winter-run Chinook salmon redds are constructed in the Sacramento River upstream of Battle Creek with 45 percent of redds occurring in the two miles between A.C.I.D. Dam and Keswick Dam and a further 56.3 percent of redds occurring between A.C.I.D. Dam and the Airport road bridge (18 RM downstream of Keswick Dam) (Table **Error! No text of specified style in document.**-16). The redd dewatering analysis presented in the BA and below relies upon the relationships between flow fluctuations and redd dewatering for Chinook salmon in the Sacramento River between Keswick Dam and Battle Creek (U.S. Fish and Wildlife Service 2006). As such, the analysis covers the Sacramento River upstream of the Battle Creek confluence and what is 99.7 percent of the habitat used for Sacramento River winter-run Chinook salmon spawning and egg incubation, based on the spatial distribution of redds from 2003-2014 (Table **Error! No text of specified style in document.**-3).

The percentage of winter-run Chinook salmon redds dewatered by reductions in Sacramento River flow was estimated using CALSIM II estimates of monthly mean flows during the three months following each month of spawning combined with the functional relationships developed in field studies by U.S. Fish and Wildlife Service (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows (BA Appendix 5D.2.2, *Spawning Flows Methods*). The analysis estimated winter-run Chinook salmon redd dewatering under the PA and NAA for the three upstream river segments (Segments 4, 5 and 6). River Segment 4 stretches 8 miles from Battle Creek to the confluence with Cow Creek; Segment 5 reaches 16 miles from Cow Creek to the A.C.I.D. Dam; and Segment 6 covers 2 miles from A.C.I.D. Dam to Keswick Dam. Detailed information on redd dewatering analysis methods is provided in the BA in Appendix 5D.2.2, *Spawning Flows Methods*.

Differences in winter-run Chinook salmon redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent of redds dewatered for the April through August months of spawning. Because river Segment 5 is the longest segment and includes the bulk of the analyzed winter-run Chinook salmon spawning area, those results are described in more detail here. The exceedance curves for the PA generally show consistently small, but higher redd dewatering percentages than those for the NAA for all water year types combined, and individually for all water year types except those that are critically dry (Figure **Error! No text of specified style in document.**-22 through Figure **Error! No text of specified style in document.**-23). The biggest differences in the dewatering curves are predicted for above normal water years, with about 25 percent of all months having greater than 10 percent of redds dewatered under the NAA, but about 38 percent of all months having greater than 10 percent of redds dewatered under the PA (a 13 percent increase).

Tabular results from the BA show the differences between the PA and NAA in the mean percentage of redds dewatered in each river segment for each month of spawning under each water year type and all water year types combined (Table **Error! No text of specified style in document.**-17). Similar to redd dewatering exceedance plots, the tabular results show a small, but consistent, difference in redd dewatering risk between the PA and NAA. The mean percent redds dewatered under the PA is predicted to range between three and seven percent greater (raw difference) than the means under the NAA during June of all water year types except wet years, and to be between three and six percent greater during August of wet and above normal years, respectively. The percent change (relative change rather than raw change) in the means for these months and water year types ranged from 26 percent to 89 percent greater under the PA than under the NAA. The large percentages for many of the months and water year types are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes. During April and May, redd dewatering would differ insignificantly between the PA and NAA.

*Table **Error! No text of specified style in document.**-18. Winter-Run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) between Model Scenarios (green indicates PA is at least five percent lower [raw difference] than NAA; red indicates PA is at least five percent higher).*

Month	WYT	NAA	PA	PA vs. NAA
April	Wet	6.1	6.0	0 (0 percent)
	Above Normal	0.8	0.9	0.14 (19 percent)
	Below Normal	0.0	0.0	0 (-61 percent)

Month	WYT	NAA	PA	PA vs. NAA
	Dry	0.4	0.2	-0.2 (-53 percent)
	Critical	1.4	1.3	-0.1 (-9 percent)
	All	2.4	2.3	-0.1 (-2 percent)
May	Wet	0.4	0.4	0 (1 percent)
	Above Normal	0.3	0.4	0.1 (31 percent)
	Below Normal	0.0	0.0	0 (0 percent)
	Dry	0.7	0.6	-0.2 (-22 percent)
	Critical	0.2	0.2	0 (10 percent)
	All	0.4	0.4	0 (-6 percent)
June	Wet	1.1	1.2	0.1 (9 percent)
	Above Normal	3.5	6.3	2.8 (79 percent)
	Below Normal	16.1	22.9	6.8 (43 percent)
	Dry	20.5	25.8	5.3 (26 percent)
	Critical	16.5	21.8	5.3 (32 percent)
	All	10.5	13.9	3.5 (33 percent)
July	Wet	10.8	14.3	3.5 (32.4 percent)
	Above Normal	17.5	18.2	0.6 (4 percent)
	Below Normal	28.5	31.8	3.3 (12 percent)
	Dry	29.8	30.9	1.1 (4 percent)
	Critical	27.7	28.0	0.3 (0.9 percent)
	All	21.4	23.3	2 (9 percent)
August	Wet	5.5	8.5	3 (55 percent)
	Above Normal	7.1	13.4	6.3 (89 percent)

Month	WYT	NAA	PA	PA vs. NAA
	Below Normal	18.9	17.9	-1 (-5 percent)
	Dry	16.5	18.5	2 (12 percent)
	Critical	21.7	20.6	-1.1 (-5 percent)
	All	12.6	14.8	2.2 (17 percent)

Another source of information suggesting that winter-run redd dewatering in the Sacramento River will increase under the PA comes from the SALMOD results presented in the BA (Table **Error! No text of specified style in document.**-18). The SALMOD model provides predicted flow-related mortality of SR winter-run Chinook salmon spawning, eggs and alevins, divided into "incubation" (which refers to redd dewatering and scour) and "superimposition" (which refers to redd overlap) mortality (see BA Attachment 5.D.2, SALMOD Model). Under the PA the number of winter-run Chinook salmon eggs and alevins predicted to die from redd dewatering and scour during incubation ranges from 244,211 in wet years to 714,331 in below normal years, with an average over all water year types of 430,651. As a percent change in mortality caused by redd dewatering and scour, the difference between the PA and the NAA ranges from a nine percent decrease in below normal years to a 5 percent increase in wet year types.

Table ***Error! No text of specified style in document.****-19. Mean Annual Winter-Run Chinook Salmon Mortality1 (# of Fish/Year) Predicted by SALMOD(green indicates PA is at least five percent lower [raw difference] than NAA; red indicates PA is at least five percent higher).*

Month	Water Year Type	NAA	PA	PA vs. NAA
July	Wet	641,799	648,643	6,844 (1%)
	Above Normal	722,286	716,128	-6,159 (-0.9%)
	Below Normal	692,543	703,019	10,476 (2%)
	Dry	630,808	620,367	-10,441 (-2%)
	Critical	571,751	541,702	-30,049 (-5%)
	All	648,435	644,090	-4,345 (-0.7%)
August	Wet	490,701	492,357	1,656 (0.3%)
	Above Normal	492,465	483,771	-8,694 (-2%)
	Below Normal	524,955	476,186	-48,770 (-9%)
	Dry	477,850	480,511	2,661 (0.6%)
	Critical	483,342	495,327	11,985 (2%)
	All	491,365	486,372	-4,992 (-1%)
September	Wet	640,883	626,609	-14,274 (-2%)
	Above Normal	476,374	478,456	2,082 (0.4%)
	Below Normal	570,367	590,554	20,186 (4%)
	Dry	581,481	589,147	7,666 (1%)
	Critical	582,039	576,547	-5,491 (-0.9%)
	All	582,243	581,821	-422 (-0.1%)
October	Wet	490,575	512,763	22,188 (5%)
	Above Normal	518,601	515,736	-2,864 (-0.6%)
	Below Normal	555,774	519,724	-36,051 (-6%)
	Dry	556,999	544,318	-12,681 (-2%)
	Critical	567,207	552,775	-14,432 (-3%)
	All	531,335	527,868	-3,467 (-0.7%)

Collectively, the estimated percentage of redd dewatering presented in the exceedance plots (Figure **Error! No text of specified style in document.**-24 through Figure **Error! No text of specified style in document.**-25) and table (Table **Error! No text of specified style in document.**-20) indicate that there is a medium degree of certainty that Sacramento River redd dewatering under the PA is a medium-level magnitude stressor to SR winter-run Chinook salmon in all water years except critically dry years, when dewatering under the PA is a low-level magnitude stressor. There is also a medium-degree of certainty that the SALMOD results show a combined effect of redd dewatering and scour under the PA places a medium-level magnitude stress on SR winter-run Chinook salmon. The certainty of these magnitude rankings is medium given the limitations of using results based on monthly flows to understand the magnitude of impacts that occur over daily time scale.

2.5.1.2.2.2 Spring-run Exposure and Risk

CV Spring-run Chinook salmon enter freshwater (Sacramento River) as immature fish, beginning in March (Yoshiyama et al. 1998). Although some CV spring-run Chinook salmon remain in the mainstem Sacramento River, many migrate far upriver and enter its tributaries, peaking around mid-April, completing by the end of July (Lindley et al. 2004). CV spring-run Chinook salmon then delay spawning for weeks or months holding in cool deep pools. Spawning occurs in September, and embryos hatch in 40 to 60 days and remain in the gravel as alevins for another 4 to 6 weeks, usually after the yolk sac is fully absorbed (NMFS 2014). Depending on water temperatures, emergence may begin as early as November, peaking in December and January, and may continue through spring (Moyle 2002).

Monitoring CV spring-run Chinook salmon spawning in the mainstem Sacramento River is complicated due to lack of spatial/geographic segregation and temporal isolation from fall-run Chinook salmon. Therefore, even though physical habitat conditions can support spawning and incubation, genetic diversity through introgression may be at risk, as well as redd superimposition (CDFG 1998). Aerial redd surveys conducted by CDFW base CV spring-run Chinook salmon redd counts on observations in the month of September. Total redds by reach from 2001 to 2016 are shown in the table below. The eight most recent years of observations (2009 to 2016) were very low, with numbers of redd observations near zero (with the exception of 57 redds in 2013), and in three of the years no surveys were completed (Table 2-23).

Table ***Error! No text of specified style in document.****-21. Spatial Distribution of Spawning Redds in the Sacramento River Based on Aerial Redd Surveys in September, 2001-2016 (source CDFW, unpublished data)*

Reach	Mean Annual Percent of Total Redds Sighted	Total Redds
Keswick to ACID Dam	12.4	56
ACID Dam to Highway 44 Bridge	32.8	108
Highway 44 Bridge to Airport Road Bridge	27.7	141
Airport Rd. Bridge to Balls Ferry Bridge	10.9	48
Balls Ferry Bridge to Battle Creek	7.3	29
Battle Creek to Jelly’s Ferry Bridge	1.5	35
Jelly’s Ferry Bridge to Bend Bridge	2.6	10
Bend Bridge to Red Bluff Diversion Dam	0.8	2
Below Red Bluff Diversion Dam	4.1	21
ACID = Anderson-Cottonwood Irrigation District		

Spring-run Chinook salmon eggs and alevins in the Sacramento River are vulnerable to dewatering from the time when spawning begins, usually in September, through alevin emergence around late December. The redd dewatering analysis presented in the BA and below relies upon the relationships between flow fluctuations and redd dewatering for Chinook salmon in the Sacramento River between Keswick Dam and Battle Creek (U.S. Fish and Wildlife Service 2006). As such, the analysis covers the Sacramento River upstream of the Battle Creek confluence, and, therefore, based on the spatial distribution of redds from 2003-2014 (**Error! Reference source not found.**), 60 percent of the habitat used for Sacramento River fall-run Chinook salmon spawning and egg incubation was analyzed for potential risks from dewatering, while the remaining 40 percent of historical spawning habitat downstream of the Battle Creek confluence was not. Differences in spring-run redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent of redds dewatered for August through October spring-run spawning. The exceedance curves for the PA generally show slightly higher redd dewatering percentages than those for the NAA for all water year types combined and substantially higher dewatering percentages for above normal and below normal water year types in particular Figure **Error! No text of specified style in document.**-26 through Figure **Error! No text of specified style in document.**-31. The biggest differences in the dewatering curves are predicted for above normal water years, with about 24 percent of all months having greater than 20 percent of redds dewatered under the NAA, but about 43 percent of all months having greater than 20 percent of redds dewatered under the PA.

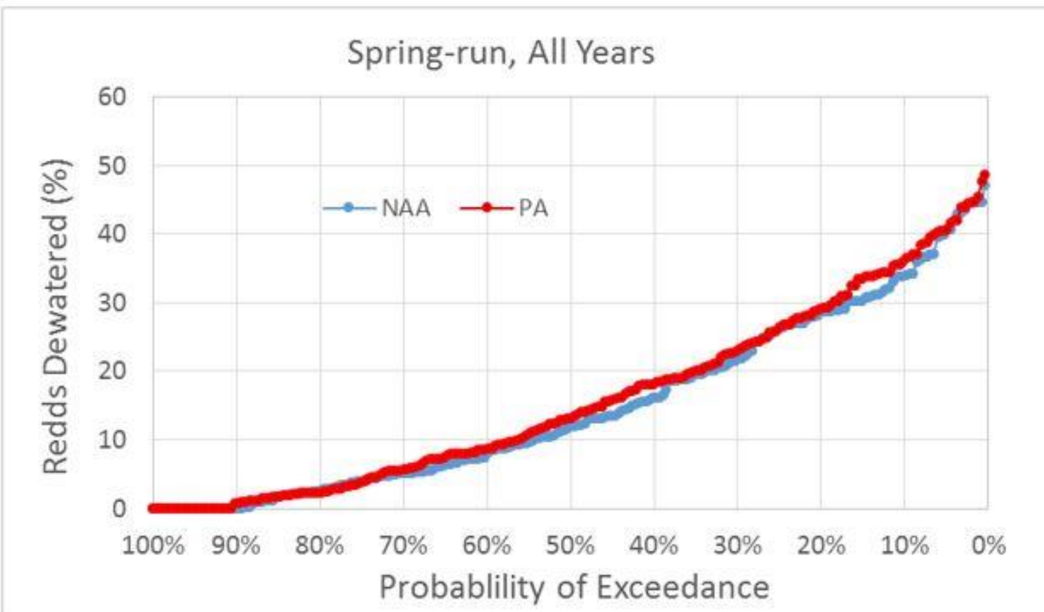


*Figure **Error! No text of specified style in document.**-26. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, All Water Years*

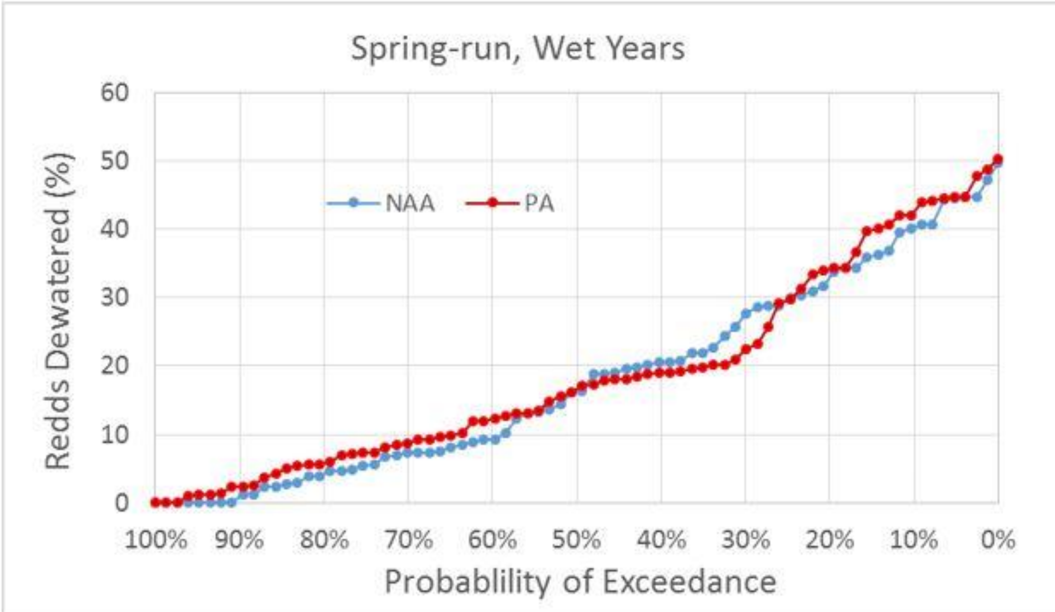


*Figure **Error! No text of specified style in document.**-27. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, All Water Years*

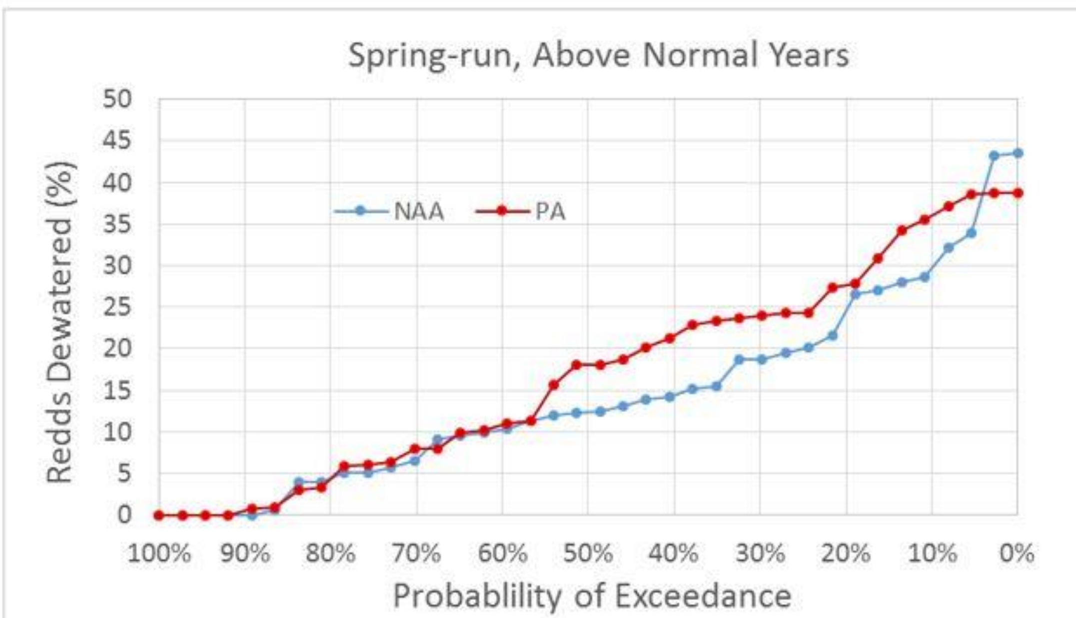


*Figure **Error! No text of specified style in document.**-28. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Above Normal Water Years*

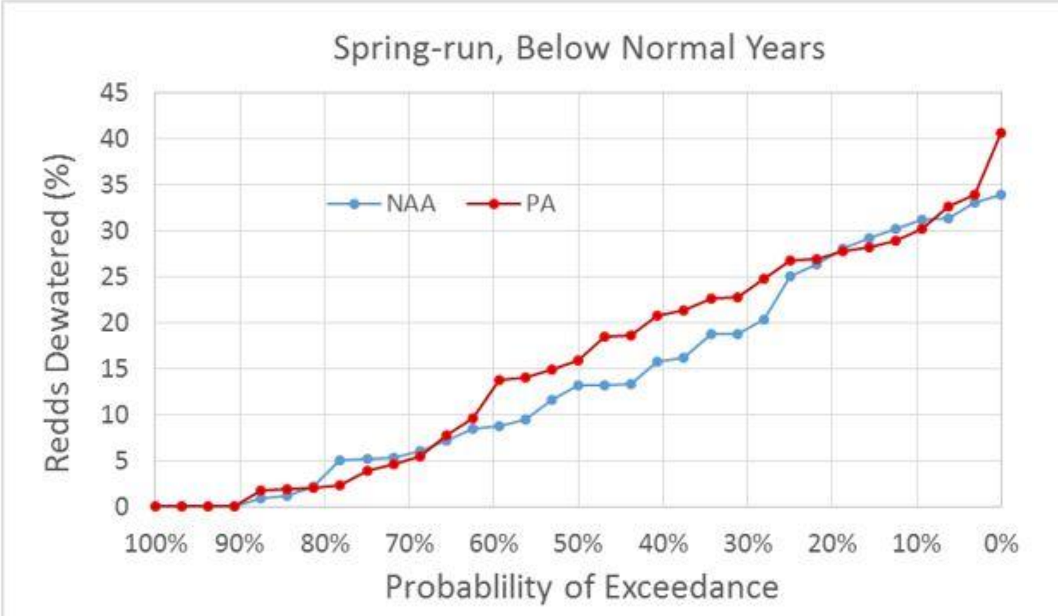


*Figure **Error! No text of specified style in document.**-29. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Below Normal Water Years*

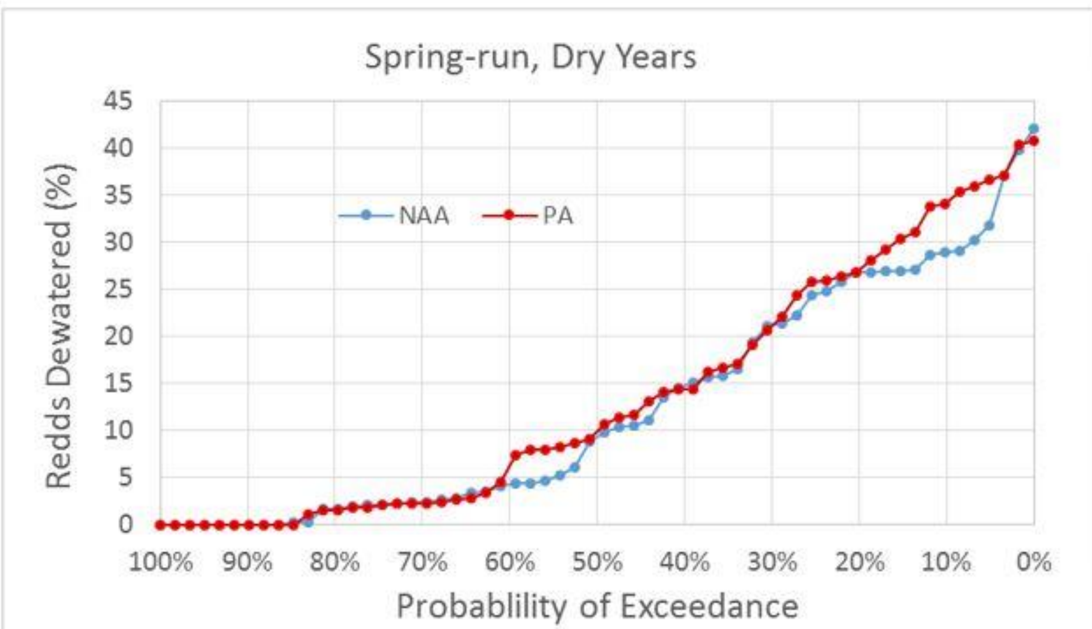


*Figure **Error! No text of specified style in document.**-30. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Dry Water Years*

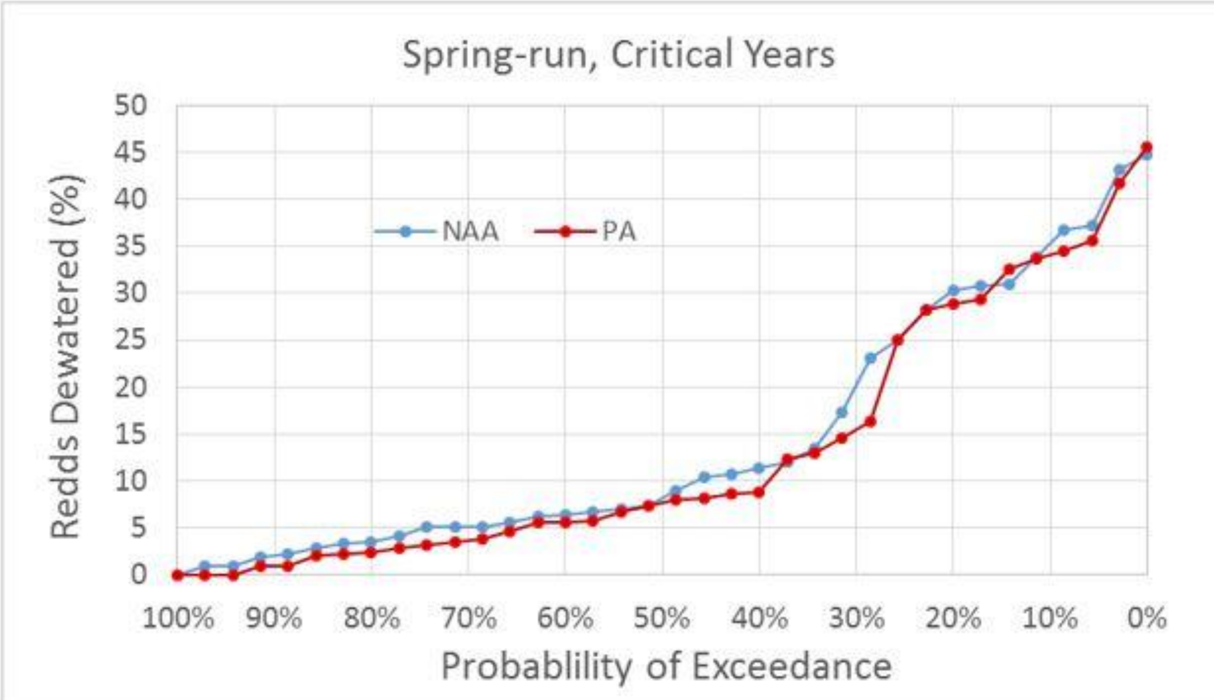


Figure ***Error! No text of specified style in document.****-31. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Critical Water Years*

Exceedance curves indicate differences in redd dewatering between the PA and NAA as examined using the mean percentages of redds dewatered in each river segment for each month of spawning under each water type and all water year types combined (Table **Error! No text of specified style in document.**-22), which may indicate an adverse effect to spring-run Chinook salmon. During August, the mean percent of redds dewatered would be five and eight percent greater under the PA than under the NAA in wet and above normal water years, respectively. During October, the mean under the PA would be five percent lower in wet years and six percent higher in below normal years. During September of below normal water years, the mean percent of redds dewatered would be up to three percent lower under the PA than under the NAA. The percent differences between the PA and the NAA in the percent of redds dewatered are generally large, but for many months and water year types this is an artifact of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes.

*Table **Error! No text of specified style in document.**-22. Spring-Run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) between Model Scenarios (green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher)*

Month	WYT	NAA	PA	PA vs. NAA
August	Wet	10.0	15.0	5 (50%)
	Above Normal	13.0	21.4	8 (64%)
	Below Normal	27.9	29.4	1 (5%)
	Dry	27.1	29.4	2 (9%)
	Critical	30.9	29.7	-1 (-4%)
	All	20.1	23.6	3 (17%)
September	Wet	30.2	31.9	2 (6%)
	Above Normal	17.9	16.5	-1 (-8%)
	Below Normal	5.6	2.7	-3 (-52%)
	Dry	3.1	1.9	-1 (-38%)
	Critical	6.0	4.4	-2 (-26%)
	All	14.8	14.2	-0.6 (-4%)
October	Wet	14.5	9.9	-5 (-32%)
	Above Normal	12.4	13.1	1 (5%)
	Below Normal	9.1	15.4	6 (70%)
	Dry	7.9	9.9	2 (26%)
	Critical	6.7	6.1	-1 (-9%)
	All	10.7	10.6	-0.1 (-1%)

The BA also used the SALMOD model to provide predicted flow-related mortality of spring-run Chinook salmon spawning, eggs and alevins in the Sacramento River. The SALMOD results for flow-related mortality are presented in Table **Error! No text of specified style in document.**-23 together with results for the other sources of mortality of spring-run Chinook salmon predicted by SALMOD. The flow-related mortality of spring-run Chinook salmon spawning, eggs, and alevins is divided into "incubation" (which refers to redd dewatering and scour) and "superimposition" (which refers to redd overlap) mortality (see Attachment 5.D.2, SALMOD Model, for full model description).

Table ***Error! No text of specified style in document.****-23. Mean Annual Spring-Run Chinook Salmon Mortality1 (# of Fish/Year) Predicted by SALMOD*

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing										
	Temperature-Related Mortality			Flow-Related Mortality				Temperature-Related Mortality				Flow-Related Mortality						
Analysis Period	**Pre-Spawn**	**Eggs**	**Subtotal**	**Incubation**	**Super-imposition**	**Subtotal**	**Life Stage Total**	**Fry**	**Pre-smolt**	**Immature Smolt**	**Subtotal**	**Fry**	**Pre-smolt**	**Immature Smolt**	**Subtotal**	**Life Stage Total**	**Grand Total**
All Water Year Types2																	
NAA	46,032	124,013	170,045	1,905	0	1,905	171,950	1	0	0	1	2,265	0	0	2,265	2,265	174,215
PA	50,462	107,473	157,935	2,118	0	2,118	160,053	0	0	0	0	2,273	0	0	2,273	2,273	162,325
Difference	4,431	-16,540	-12,110	212	0	212	-11,898	-1	0	0	-1	8	0	0	8	7	-11,890
Percent Difference[3]	10	-13	-7	11	0	11	-7	-100	0	0	-100	0	0	0	0	0	-7
Water Year Types4																	
Wet (32.5%)																	
NAA	116	6,530	6,646	1,336	0	1,336	7,983	0	0	0	0	2,614	0	0	2,614	2,614	10,597
PA	117	5,835	5,952	1,748	0	1,748	7,699	0	0	0	0	2,815	0	0	2,815	2,815	10,514
Difference	1	-695	-695	411	0	411	-283	0	0	0	0	200	0	0	200	200	-83
Percent Difference	0	-11	-10	31	0	31	-4	0	0	0	NA5	8	0	0	8	8	-1
Above Normal (12.5%)																	
NAA	78	4,181	4,258	1,162	0	1,162	5,420	0	0	0	0	2,703	0	0	2,703	2,703	8,124
PA	65	3,888	3,953	1,509	0	1,509	5,463	0	0	0	0	2,354	0	0	2,354	2,354	7,816
Difference	-12	-293	-305	347	0	347	42	0	0	0	0	-350	0	0	-350	-350	-307
Percent Difference	-16	-7	-7	30	0	30	1	0	0	0	NA	-13	0	0	-13	-13	-4
Below Normal (17.5%)																	
NAA	154	34,929	35,084	1,300	0	1,300	36,384	0	0	0	0	2,634	0	0	2,634	2,634	39,018
PA	309	41,242	41,551	1,711	0	1,711	43,262	0	0	0	0	2,591	0	0	2,591	2,591	45,853
Difference	155	6,313	6,467	411	0	411	6,878	0	0	0	0	-43	0	0	-43	-43	6,835
Percent Difference	100	18	18	32	0	32	19	0	0	0	NA	-2	0	0	-2	-2	18
Dry (22.5%)																	
NAA	1,093	66,312	67,406	3,652	0	3,652	71,058	0	0	0	0	2,468	0	0	2,468	2,468	73,526
PA	995	64,050	65,045	3,422	0	3,422	68,467	0	0	0	0	2,438	0	0	2,438	2,438	70,905
Difference	-98	-2,263	-2,361	-230	0	-230	-2,591	0	0	0	0	-30	0	0	-30	-30	-2,621
Percent Difference	-9	-3	-4	-6	0	-6	-4	0	0	0	NA	-1	0	0	-1	-1	-4
Critical (15%)																	
NAA	304,677	671,412	976,089	1,670	0	1,670	977,759	3	0	0	3	408	0	0	408	411	978,170
PA	334,238	560,737	894,976	1,835	0	1,835	896,811	0	0	0	0	463	0	0	463	463	897,274
Difference	29,562	-110,675	-81,113	165	0	165	-80,949	-3	0	0	-3	55	0	0	55	52	-80,897
Percent Difference	10	-16	-8	10	0	10	-8	-100	0	0	-100	14	0	0	14	13	-8

[1] Mortality values do not include base mortality
[2] Based on the 80-year simulation period
[3] Relative difference of the Annual average
[4] As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (State Water Resources Control Board 1995{ TC "SWRCB 1995" \f C \l "1" }). Water years may not correspond to the biological years in SALMOD.
[5] NA = Unable to calculate because dividing by 0

The annual exceedance plot of flow-related mortality of spring-run Chinook salmon spawning, eggs and alevins is presented in Figure **Error! No text of specified style in document.**-32. These results indicate that there would be increases in flow-related mortality of spring-run Chinook salmon spawning, eggs and alevins from incubation-related factors under the PA relative to the NAA for all water year types except dry years. The largest increases, about 30 percent, would be for wet, above normal and below normal water year types. Under the PA, the number of spring-run Chinook salmon eggs and alevins predicted to die from redd dewatering and scour during incubation ranges from 1,509 in above normal years to 3,422 in dry years.

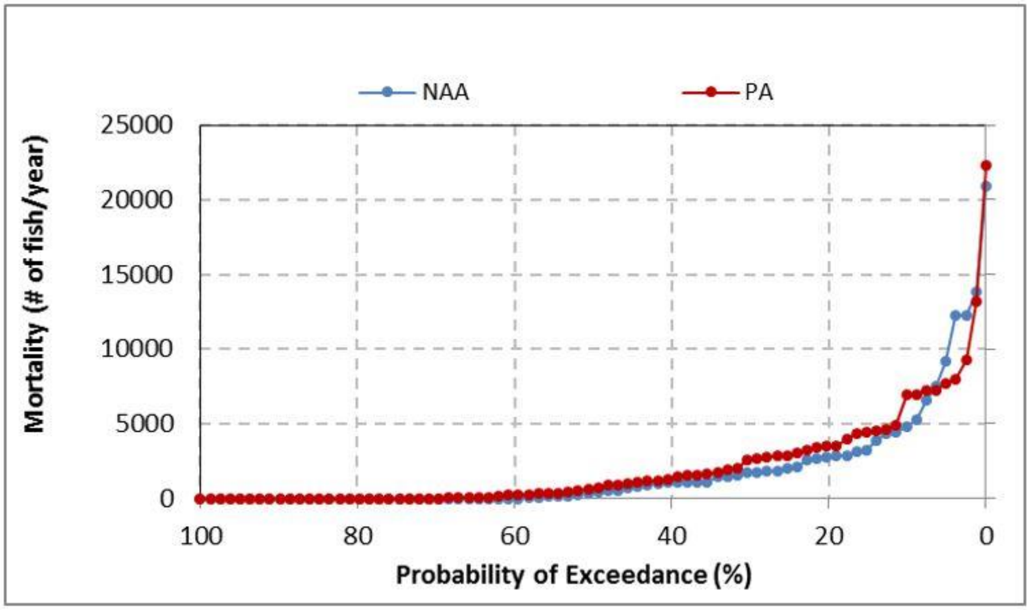


*Figure **Error! No text of specified style in document.**-32. Exceedance Plot of Annual Flow-Based Mortality (#of Fish/Year) of Spring-Run Chinook Salmon Spawning, Egg Incubation, and Alevins*

Although there may be some increases in flow-related mortality for spring-run Chinook salmon redds/eggs in some years under the PA, redd dewatering under the PA is a low magnitude stressor. The certainty of this magnitude ranking is medium given the limitations of using results based on monthly flows to understand the magnitude of impacts that occur over daily time scale as well as some difficulty in quantifying adverse effects when considering the uncertainties of spring-run Chinook salmon spawning in the upper Sacramento River. Any realized adverse effects would be limited to a very small proportion of the population.

2.5.1.2.2.3 Steelhead Exposure and Risk

2.5.1.2.2.3.1 Sacramento River

Adult migration from the ocean to spawning grounds occurs during much of the year, with peak migration occurring in the fall or early winter (figures A and B from McEwan (2001)). Migration through the Sacramento River mainstem begins in July, peaks at the end of September, and continues through February or March (Bailey 1954; Hallock et al. 1961, both as cited in McEwan and Jackson 1996). Counts made at RBDD from 1969 through 1982 (Hallock 1989), as cited in McEwan and Jackson 1996 and McEwan 2001 and on the Feather River (Painter et al. 1977) follow the pattern described above, although some fish were counted as late as April and May. Weekly counts at Clough Dam on Mill Creek during a 10-year period from 1953 to 1963 showed a similar migration pattern as well. The migration peaked in mid-November and again in February. This second peak is not reflected in counts made in the Sacramento River mainstem (Bailey 1954; Hallock et al. 1961, both as cited in McEwan and Jackson 1996 or at RBDD (Hallock 1989), as cited in McEwan and Jackson 1996, and McEwan 2001.

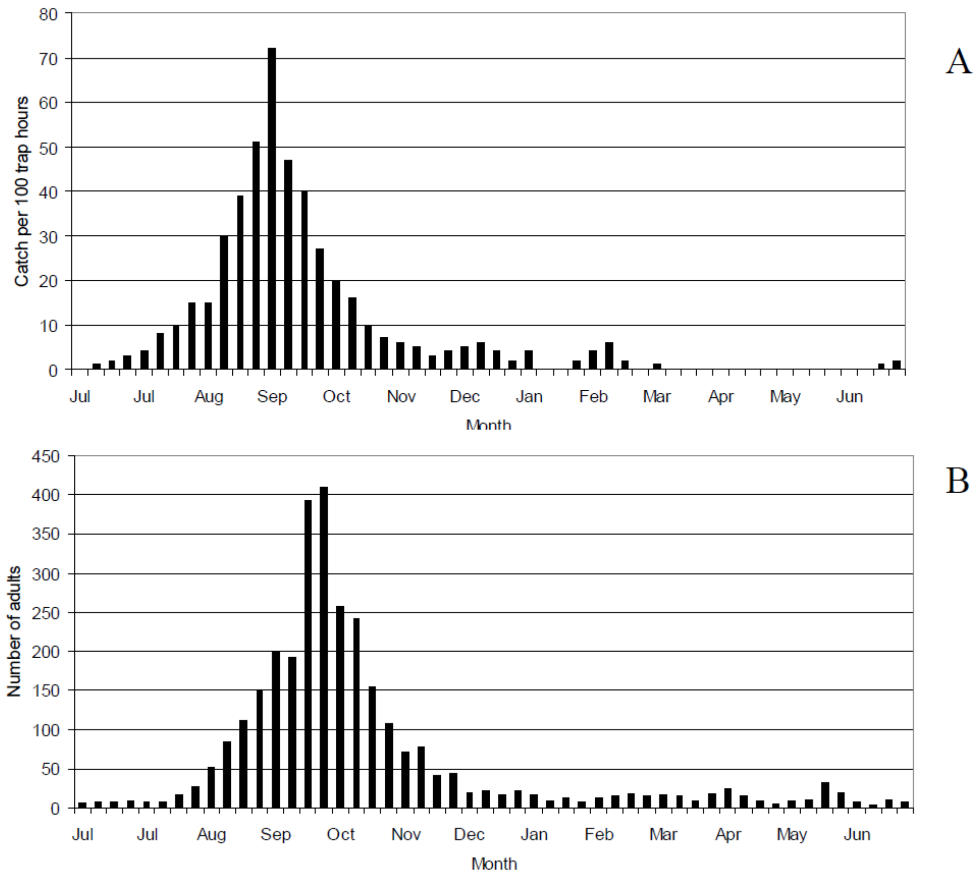


*Figure **Error! No text of specified style in document.**-33. Figures A and B. Time pattern of Sacramento River adult steelhead migration*

Figure A shows migration timing from July through June of 1953 through 1959, determined by trapping upstream migrants in the Sacramento River just upstream of the confluence with the Feather River (from Hallock et al. (1961) and others). Figure B shows the weekly average number of adult steelhead counted at Red Bluff Diversion Dam from July through June of 1983 through 1986 (from Figure 2, McEwan (2001)).

Historically, Central Valley steelhead spawned primarily in upper stream reaches and smaller tributaries, although steelhead spawn in most available channel types in unimpounded stream reaches of the Pacific Northwest (Montgomery et al. 1999). Because of water development projects, most spawning is now confined to lower stream reaches below dams. In a few streams, such as Mill and Deer Creeks, steelhead still have access to historical spawning areas. Peak spawning generally occurs from December through April (McEwan and Jackson 1996, McEwan 2001), but CCV steelhead may spawn in the Sacramento River and eggs and alevins remain in the gravel from November to May.

Recent steelhead monitoring data are scarce for the Upper Sacramento River system, but population numbers are considered to be low. There is a strong resident component to the population (referred to as rainbow trout) that interacts with the steelhead population and produces both resident and anadromous offspring. Little is known about steelhead spawning locations in the Sacramento River below Keswick Dam. It was assumed for the analysis of the PA that because of constraints on water temperature and other habitat features, individuals spawn between Keswick Dam and Red Bluff Diversion Dam, where nearly all Chinook salmon spawn. After spawning, steelhead adults either die or emigrate back to the ocean as kelts between February and May.

The time required for egg development is approximately four weeks, but is temperature-dependent (McEwan and Jackson 1996). For northern steelhead populations, optimal egg development occurs at 48 to 52°F. Egg mortality may begin at temperatures above 56°F in northern populations (Bovee 1978; Reiser and Bjornn 1979; and Bell 1986, all as cited in McEwan and Jackson (1996)). After hatching, the yolk-sac fry or alevins remain in the gravel for another four to six weeks (Shapovalov and Taft 1954, as cited in McEwan and Jackson 1996). At 50°F steelhead, fry emerge from the gravel about 60 days after egg fertilization (Leitritz and Lewis 1980).

CCV steelhead eggs and alevins in the Sacramento River are vulnerable to dewatering from the time when spawning begins in November through the end of alevin emergence in May. The BA provided modeled results on the estimated percentage of steelhead redds dewatered by reductions in Sacramento River flow using CALSIM II estimates of mean monthly flows during the three months following each of the months that steelhead spawn (Section 5.D.2.2, *Spawning Flows Methods*, Table SFM-1). This analysis employed functional relationships developed in field studies by USFWS (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows. Segment 5 CALSIM II flows were used for the effects analysis to estimate redd dewatering under the PA and NAA. Because the CALSIM II flows for Segments 4 and 6 are similar to those for Segment 5, redd dewatering estimates using the Segment 4 and Segment 6 flows differ little from those for Segment 5 (Appendix 5.D, Section 5.D.2.6, *Redd Dewatering Results, Sacramento River Segments 4 and 6*). Further information on the redd dewatering analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Differences in steelhead redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent of redds dewatered for the months that steelhead spawn (November through February) (Figure Error**! No text of specified style in document.**-34 through Figure Error**! No text of specified style in document.**-39).

Exceedance curves for wet and above normal water years indicate that frequencies of dewatering in the middle of the range of redd dewatering percentages would be lower under the PA than under the NAA, but that the frequencies would be similar under the two scenarios for the high and low portions of the range. For the other water year types, frequencies would be similar throughout the range of percentages. The differences for wet years show that under both scenarios—approximately 50 percent of the time—10 percent of the redds will be dewatered. Between 50 percent exceedance and 15 percent exceedance, the difference between the NAA and PA is about 10 to 15 percent, with the PA having a lower incidence of redd dewatering. Both scenarios start tracking together again at 15 percent exceedance when the percentage of redds dewatered reaches approximately 50 percent. In 10 percent of the years, the percentage of redds dewatered can reach approximately 75 percent. The difference between the NAA and PA in above normal years is even greater than in wet years, reaching a maximum of about 30 percent at about 25 percent exceedance. Like the wet years, 10 percent of the redds are dewatered about

50 percent of the time for both scenarios. At 25 percent exceedance, the NAA scenario model has about 50 percent of the redds dewatered, while the PA has approximately 22 percent of the redds dewatered. By 20 percent exceedance, both scenarios are again tracking together and approximately 55 percent of the redds are dewatered. About 75 percent of the redds will be dewatered 15 percent of the time, based on the modeling for both scenarios. In the remaining water year types, typically less than 10 percent of the redds are dewatered for about 80 percent of the time.

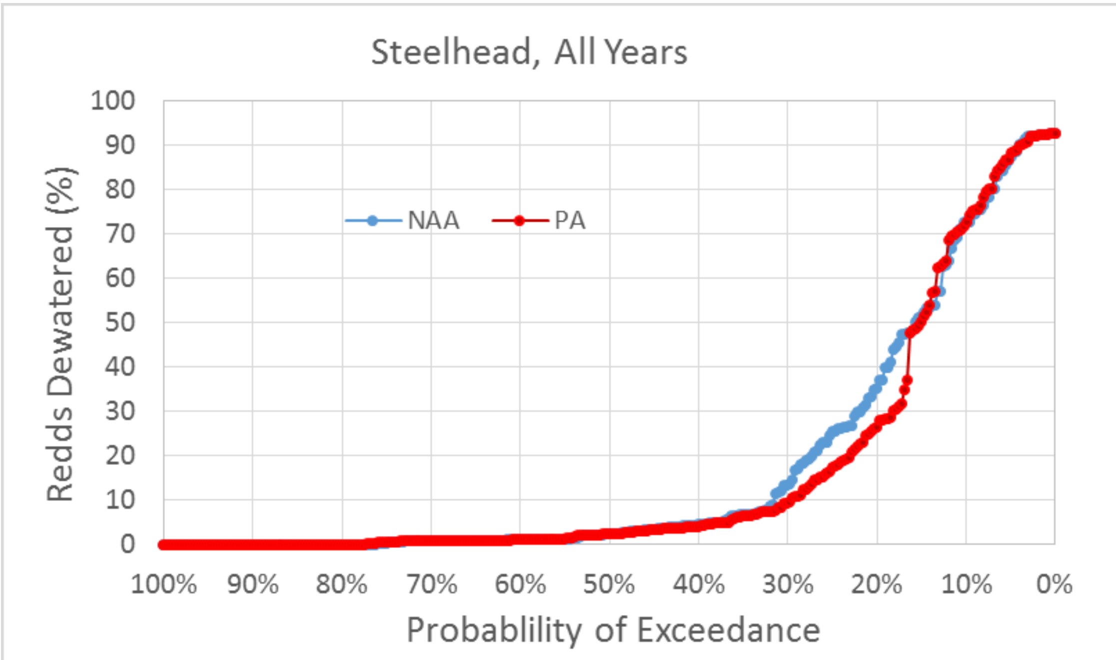


*Figure **Error! No text of specified style in document.**-34. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, All Water Years.*

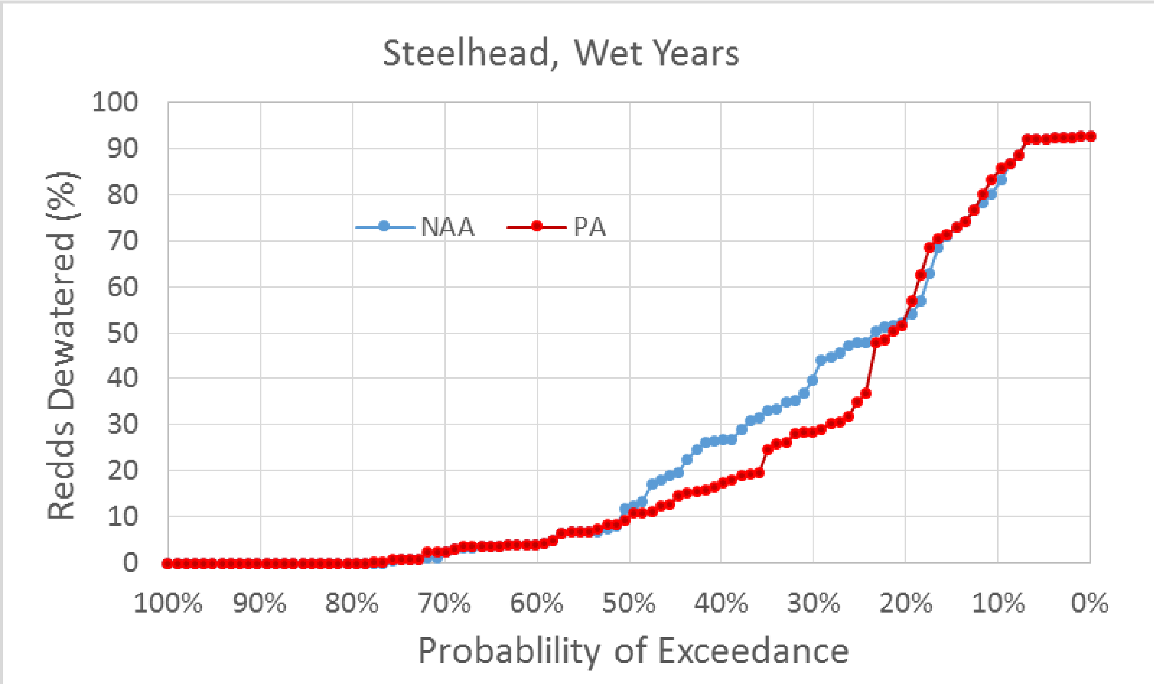


*Figure **Error! No text of specified style in document.**-35. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Wet Water Years.*

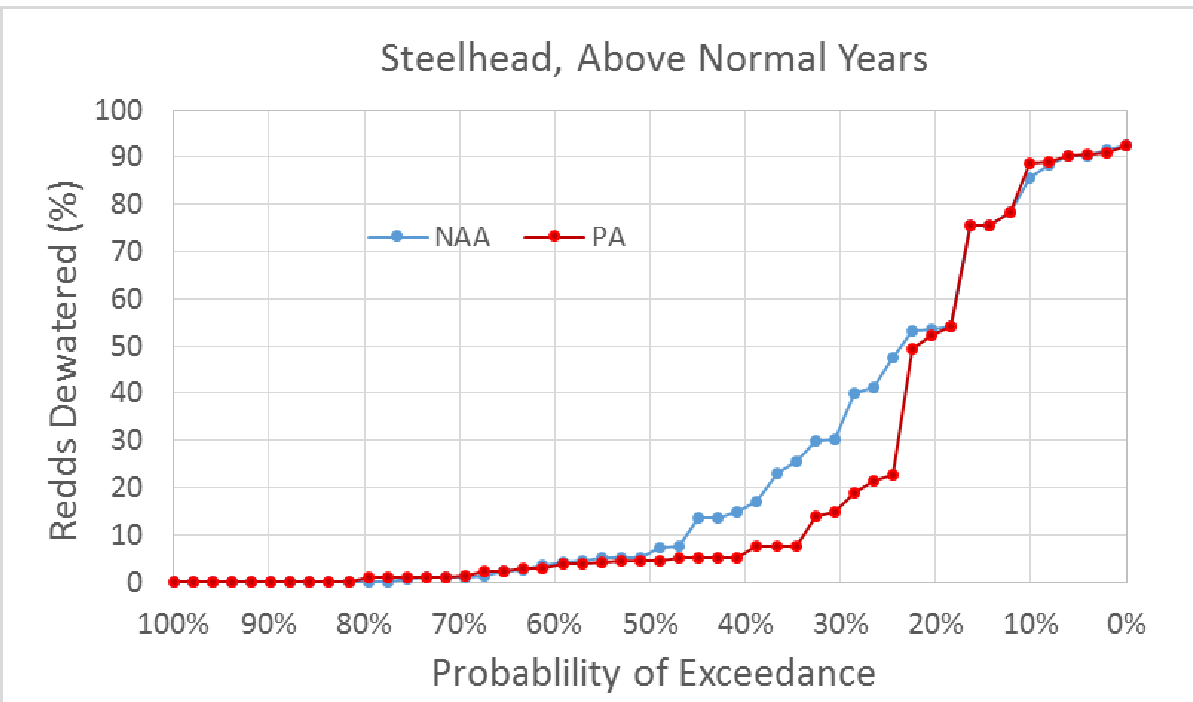


*Figure **Error! No text of specified style in document.**-36. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Above Normal Water Years.*

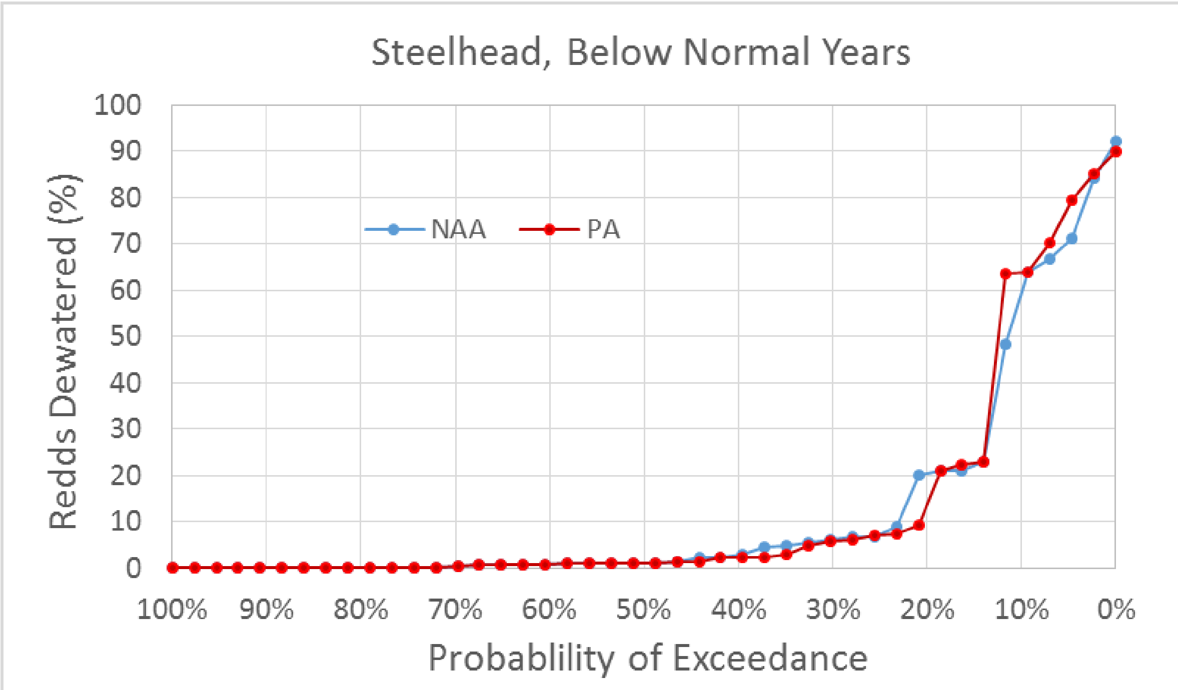


*Figure **Error! No text of specified style in document.**-37. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Below Normal Water Years.*

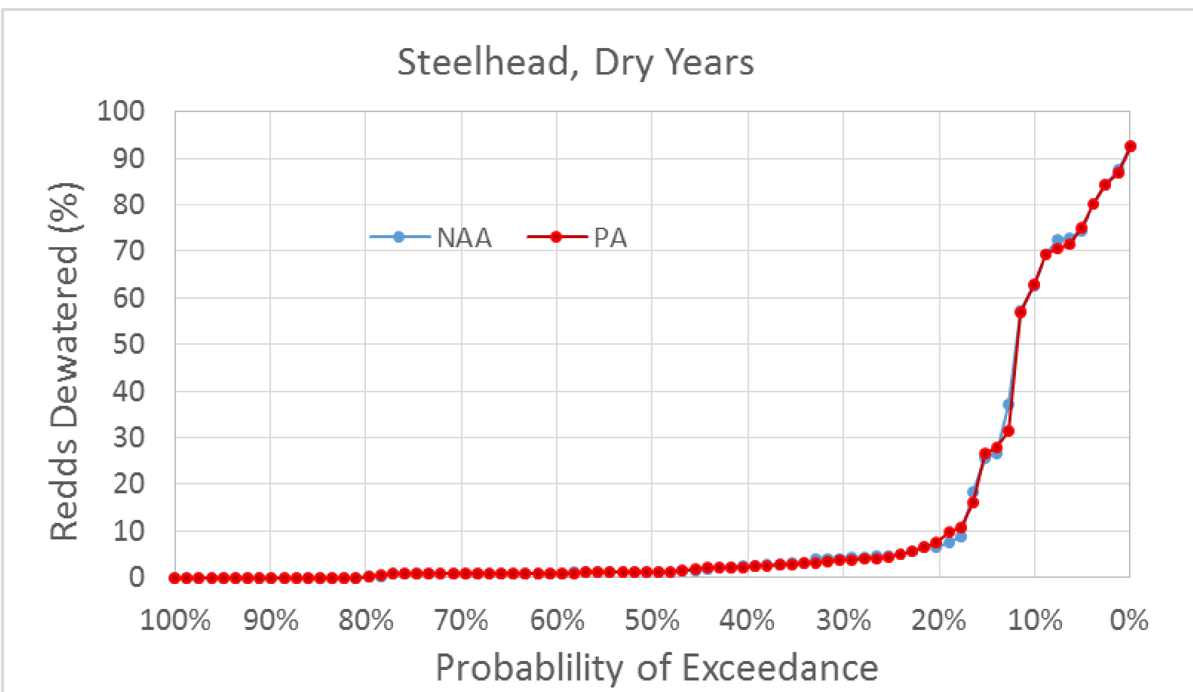


*Figure **Error! No text of specified style in document.**-38. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Dry Water Years.*

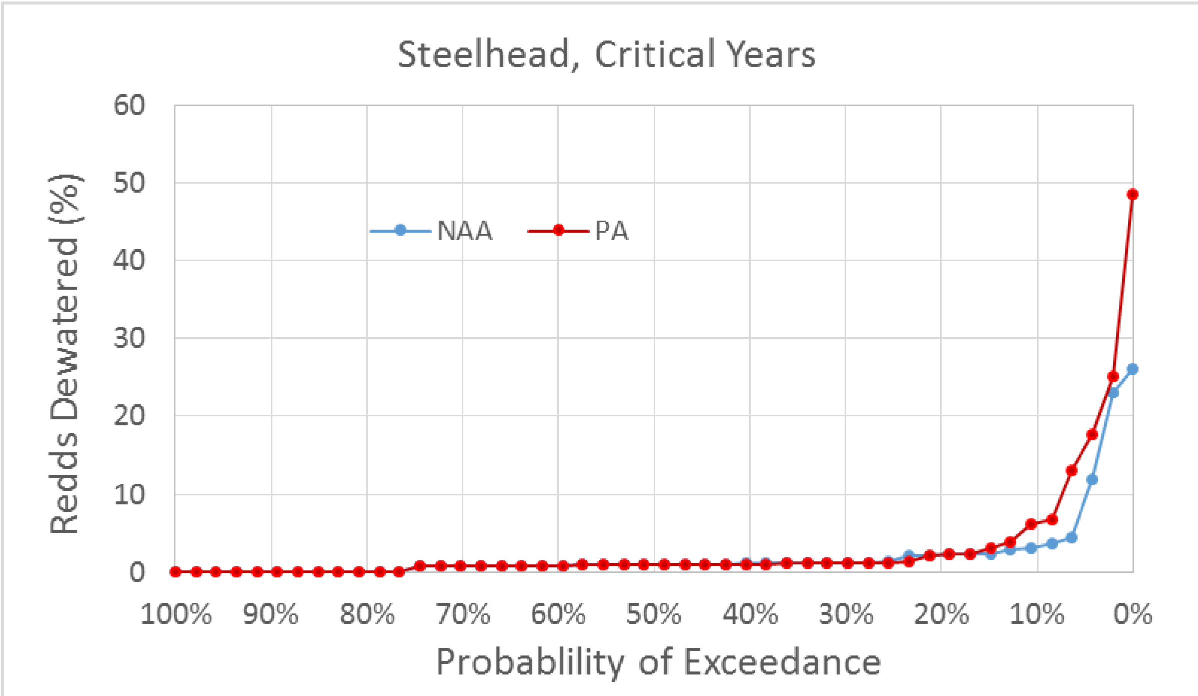


*Figure **Error! No text of specified style in document.**-39. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Critical Water Years.*

Differences in the mean percentage of redds dewatered in each river segment for each month of spawning under each water year type and all water year types combined also indicate that the PA would minimally affect steelhead redd dewatering, except for reductions in the mean percent of redds dewatered during November of wet and above normal water year types (Table **Error! No text of specified style in document.**-24). The percent differences between the PA and the NAA in the percent of redds dewatered range up to a 58 percent increase under the PA for January of critical water years, but this increase and many of the large relative changes in percent of redds dewatered are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes.

*Table **Error! No text of specified style in document.**-24. Central Valley Steelhead Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) between Model Scenarios (green indicates PA is at least 5 percent lower [raw difference] than NAA; red indicates PA is at least 5 percent higher)*

Month	WYT	NAA	PA	PA vs. NAA
November	Wet	29.4	15.6	-13.8 (-47%)
	Above Normal	29.1	15.5	-13.55 (-47%)
	Below Normal	6.6	5.0	-1.6 (-24%)
	Dry	4.5	3.4	-1.1 (-24%)
	Critical	1.9	4.7	2.8 (153%)
	All	16.0	9.5	-6.5 (-41%)
December	Wet	14.0	14.7	0.7 (5%)
	Above Normal	10.2	8.9	-1.3 (-13%)
	Below Normal	11.8	11.7	-0.1 (-1%)
	Dry	22.2	22.3	0.1 (1%)
	Critical	1.1	1.0	-0.1 (-11%)
	All	13.3	13.3	0 (0%)
January	Wet	22.6	26.0	3.5 (15%)
	Above Normal	14.2	14.3	0.1 (1%)
	Below Normal	14.7	14.2	-0.6 (-4%)
	Dry	21.5	21.9	0.4 (2%)
	Critical	2.6	6.7	4.1 (158%)
	All	17.0	18.8	1.8 (10%)
February	Wet	43.5	44.2	0.8 (1.8%)
	Above Normal	47.7	47.9	0.1 (0%)
	Below Normal	18.8	21.8	3 (16%)
	Dry	1.0	1.1	0.1 (12%)
	Critical	3.6	0.6	-3.1 (-84.1%)
	All	24.6	24.9	0.2 (1%)

2.5.1.2.2.3.2 American River

CCV steelhead eggs and alevins in the American River are vulnerable to dewatering from the time when spawning begins in December through the end of alevin emergence in May. The BA provided modeled results on the estimated percentage of steelhead redds dewatered by reductions in American River flow using CALSIM II estimates of mean monthly flows during the 3 months following each of the months that steelhead spawn. No model for predicting percentages of redds dewatered, such as that developed for the Sacramento River (U.S. Fish and Wildlife Service 2006), has been developed for the American River. Therefore, the maximum reduction in American River flow for the three months following each of the months during which steelhead spawn was used as a proxy for percent of redds dewatered. CALSIM II flows at Nimbus were used for this analysis. Larger maximum reductions are assumed to increase the percent of redds dewatered and, therefore, to have a negative effect on steelhead. Further information on redd dewatering analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Differences in maximum flow reductions under the PA and NAA were examined using exceedance plots of mean monthly maximum flow reductions, expressed as a percentage of the spawning flows, for the months that American River steelhead spawn (December through

February) (BA **Error! Reference source not found.** through **Error! Reference source not found.**; Figures 2-43 and 2-44**)**

Exceedance curves for all water year types combined (BA Figure 5.4-258; Figure 2-43) and those for wet, above normal, below normal, and dry water years (BA **Error! Reference source not found.** through **Error! Reference source not found.**: Figure 2-44) indicate that the PA would generally have slightly greater flow reductions than the NAA. These differences are typically minor, with a magnitude of approximately 5 to 15 percent. The exceedance curve for critical years appears to indicate a pronounced increase in flow reductions for the PA of up to approximately 40 percent (Figure **Error! No text of specified style in document.**-40).

However, further inspection, as referenced in the BA, reveals that increased reductions result from differences in only three months out of the 36 critical water year months of the CCV steelhead spawning period in the American River, with all of these months occurring in the same year (1933). The large magnitude of reduced flows in March 1933 under the PA appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs, resulting in higher releases from Keswick Dam and lower releases from Folsom for this month.

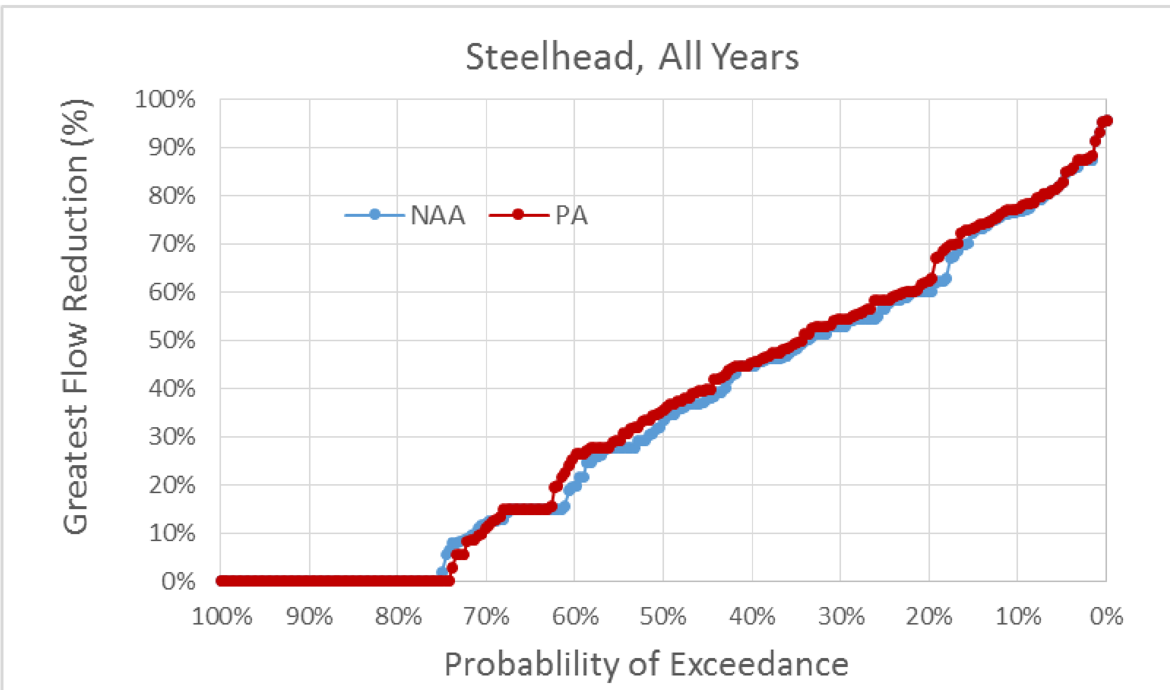


*Figure **Error! No text of specified style in document.**-41. Figure 5.4-254. Exceedance Plot of Maximum Flow Reductions (percent) for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, All Water Years.*

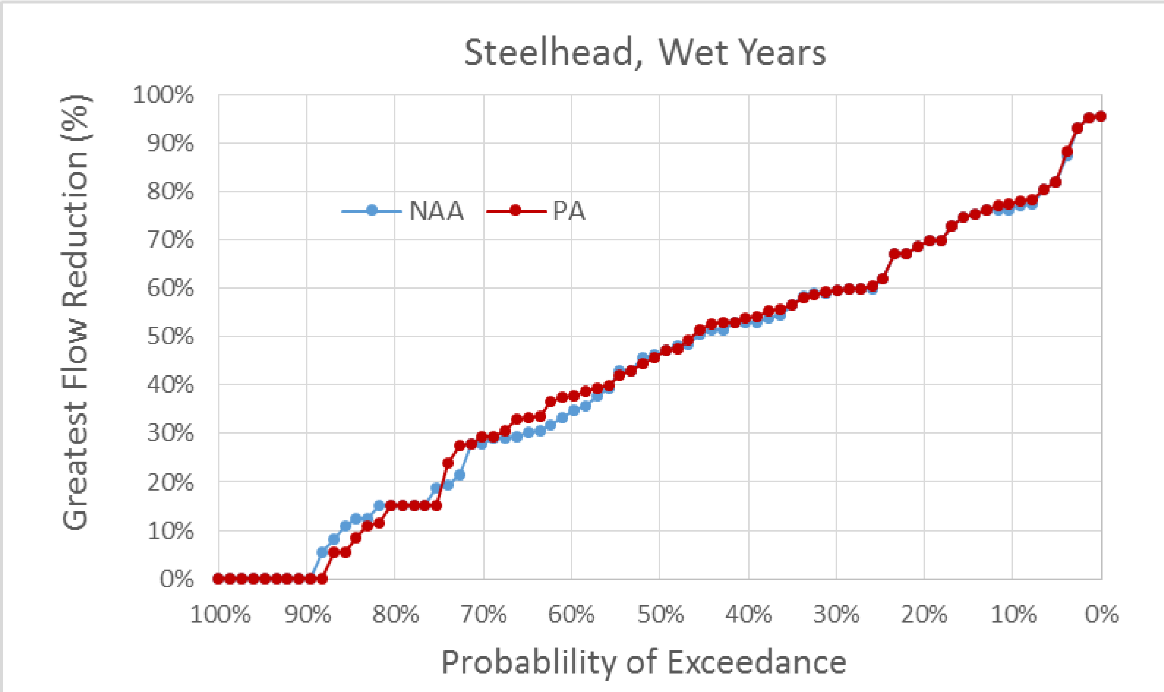


*Figure **Error! No text of specified style in document.**-42. Figure 5.4-255. Exceedance Plot of Maximum Flow Reductions (percent) for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Wet Water Years.*

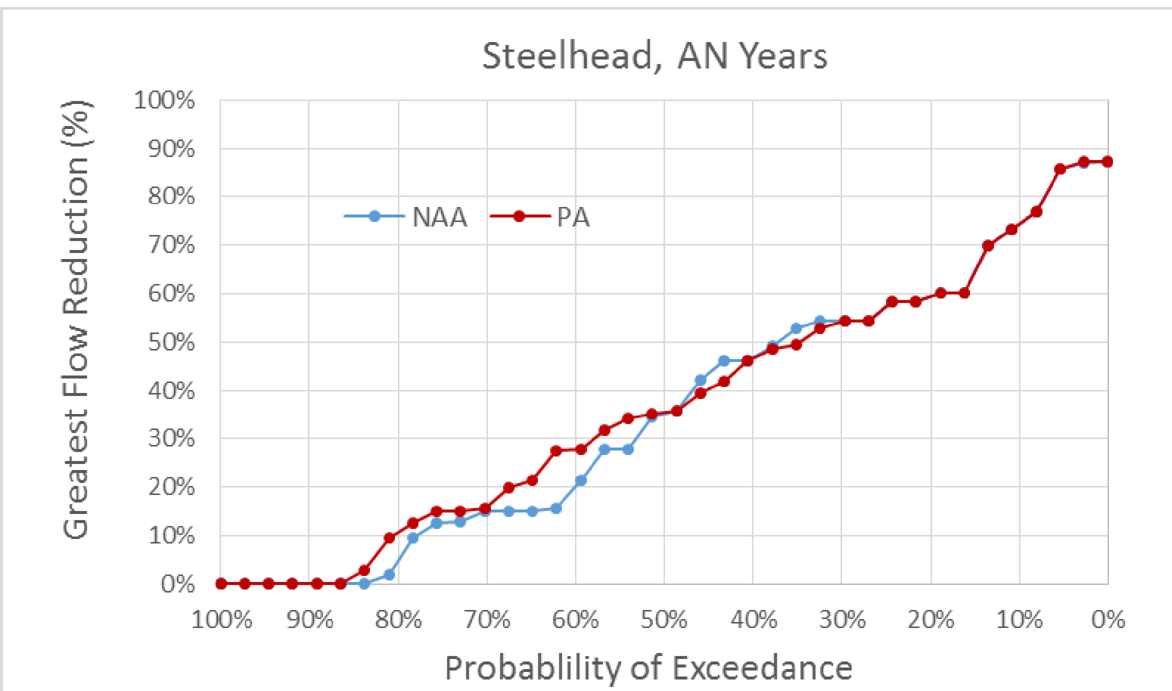


*Figure **Error! No text of specified style in document.**-43. Figure 5.4-256. Exceedance Plot of Maximum Flow Reductions (percent) for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Above Normal Water Years.*

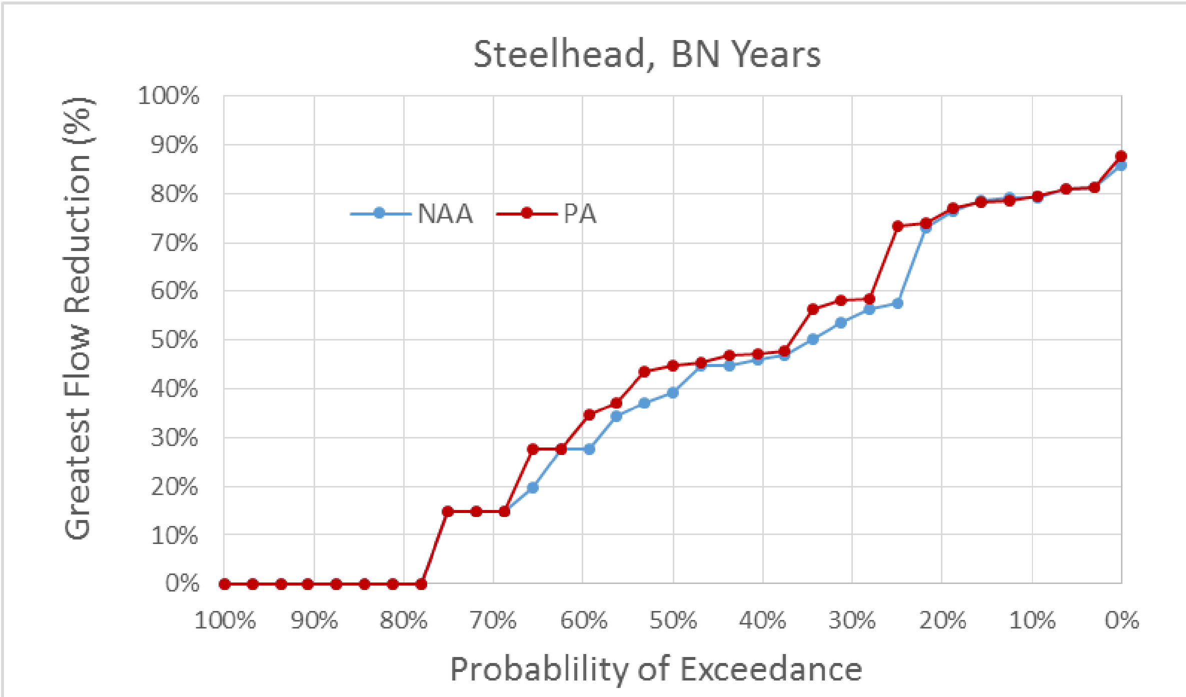


*Figure **Error! No text of specified style in document.**-44. Figure 5.4-257. Exceedance Plot of Maximum Flow Reductions (percent) for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Below Normal Water Years.*

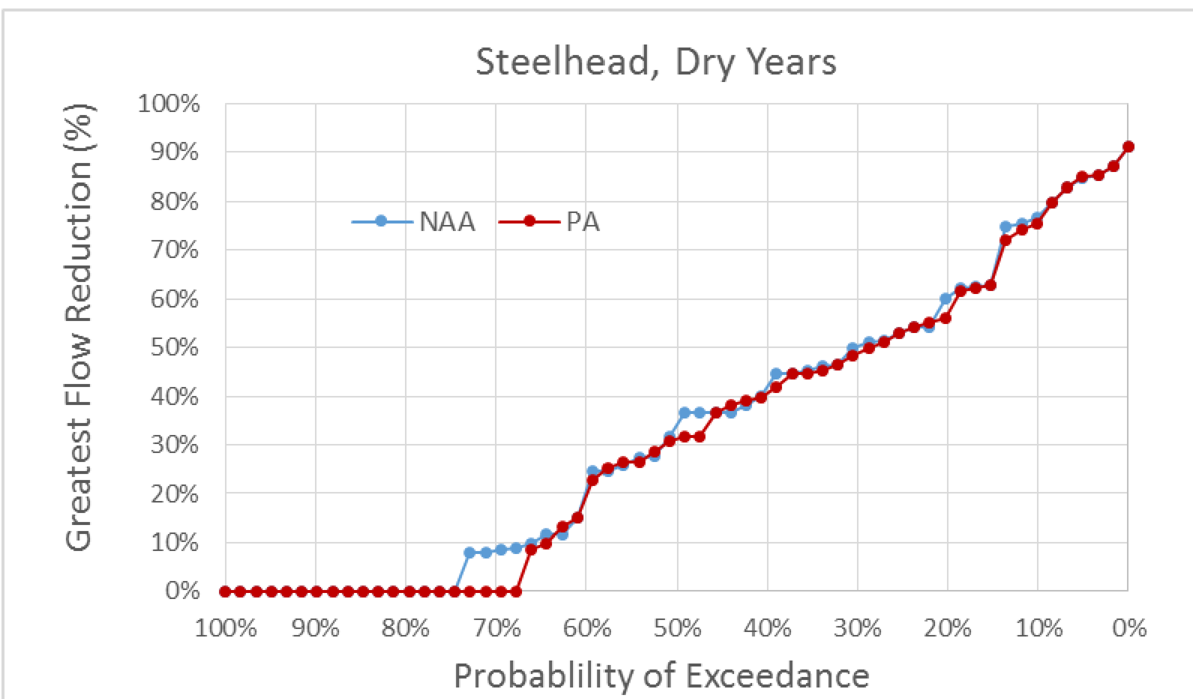


*Figure **Error! No text of specified style in document.**-45. Figure 5.4-258. Exceedance Plot of Maximum Flow Reductions for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Dry Water Years.*

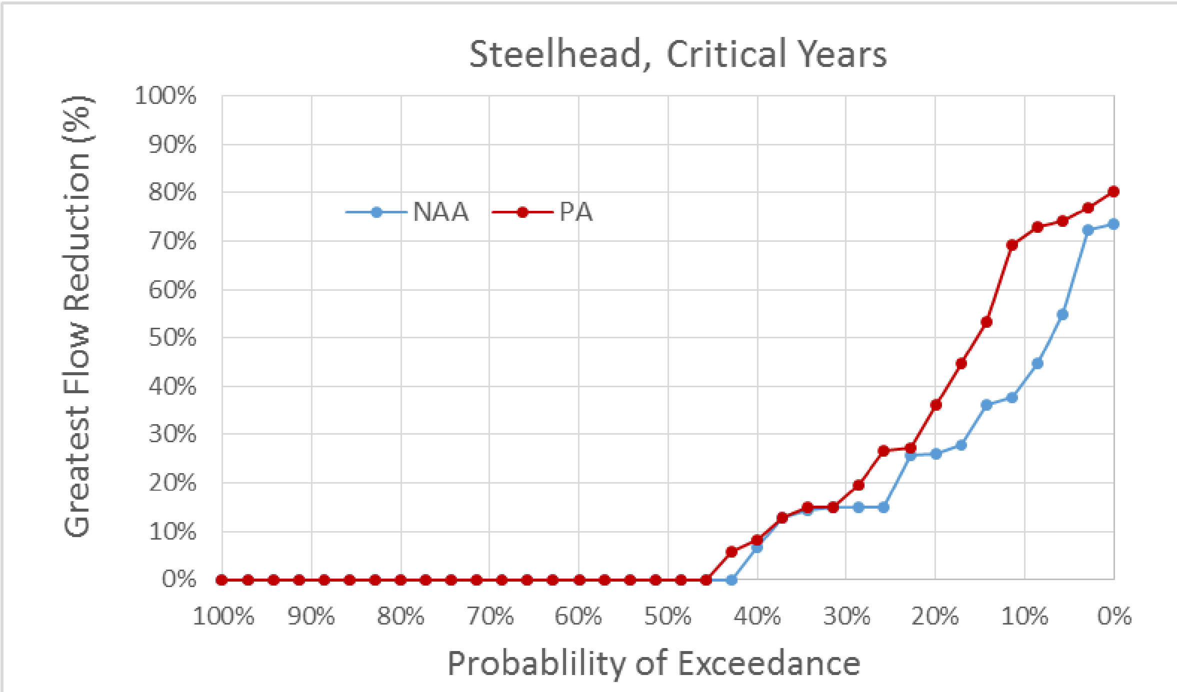


*Figure **Error! No text of specified style in document.**-46. Figure 5.4-259. Exceedance Plot of Maximum Flow Reductions for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Critical Water Years.*

Differences in the mean maximum flow reduction, expressed as a percentage of the spawning flow, for each month of spawning under each water year type and all water year types combined indicate that steelhead redd dewatering would generally be little affected by the PA (less than five percent raw difference), except for a five percent increase in the maximum flow reduction for January of critical years and six and seven percent increases for February of below normal and critical years, respectively. As previously noted, increases in flow reduction are assumed to increase redd dewatering, negatively affecting steelhead.

*Table **Error! No text of specified style in document.**-25. Maximum Flow Reductions (cfs) for 3-Month Period after Central Valley Steelhead Spawning, and Differences in the Maximums (Percent Differences) between Model Scenarios (green indicates PA is at least 5 percent lower [raw difference] than NAA; red indicates PA is at least 5 percent higher)*[1]

		Mean Greatest Flow Reduction, as Percent		Raw Difference	Relative (Percent) Difference
Month	**WYT**	**NAA**	**PA**	**PA vs. NAA**	**PA vs. NAA**
December	Wet	33.3 percent	33.5 percent	0.2 percent	0.7 percent
	Above Normal	29.1 percent	29.0 percent	-0.1 percent	-0.2 percent
	Below Normal	24.3 percent	24.3 percent	0.0 percent	-0.2 percent
	Dry	35.8 percent	32.9 percent	-2.9 percent	-8.2 percent
	Critical	15.8 percent	17.1 percent	1.3 percent	8.2 percent
	All	29.5 percent	29.0 percent	-0.5 percent	-1.6 percent
January	Wet	42.4 percent	42.3 percent	0.0 percent	-0.1 percent
	Above Normal	27.0 percent	26.9 percent	-0.2 percent	-0.6 percent
	Below Normal	40.2 percent	40.3 percent	0.1 percent	0.2 percent
	Dry	35.8 percent	36.1 percent	0.2 percent	0.6 percent
	Critical	8.1 percent	13.2 percent	5.0 percent	61.8 percent
	All	33.0 percent	33.8 percent	0.8 percent	2.3 percent
February	Wet	53.5 percent	54.3 percent	0.8 percent	1.4 percent
	Above Normal	50.7 percent	54.6 percent	3.9 percent	7.7 percent
	Below Normal	50.5 percent	56.5 percent	6.0 percent	11.9 percent
	Dry	28.1 percent	27.7 percent	-0.4 percent	-1.3 percent
	Critical	15.8 percent	22.8 percent	7.0 percent	44.5 percent
	All	41.0 percent	43.6 percent	2.6 percent	6.4 percent

[1] Increased flow reduction is assumed to increase redd dewatering, negatively affecting steelhead.

2.5.1.2.2.4 Green Sturgeon Exposure and Risk

As previously described, green sturgeon spawning primarily occurs in deep pools containing small to medium sized gravel, cobble or boulder substrate in cool sections of the upper mainstem Sacramento River. Because green sturgeon spawn in deep pools, they are not vulnerable to redd dewatering as a result of flow management in the upper Sacramento River, although water flow is undoubtedly an important habitat parameter that cues spawning migration for sDPS green sturgeon and may influence larval abundance and distribution as well (Benson et al. 2007; Erickson and Webb 2007; Heublein et al. 2009; Poytress et al. 2015).

2.5.1.2.2.5 Fall/Late Fall-run Species Exposure and Risk

2.5.1.2.2.5.1 Sacramento River

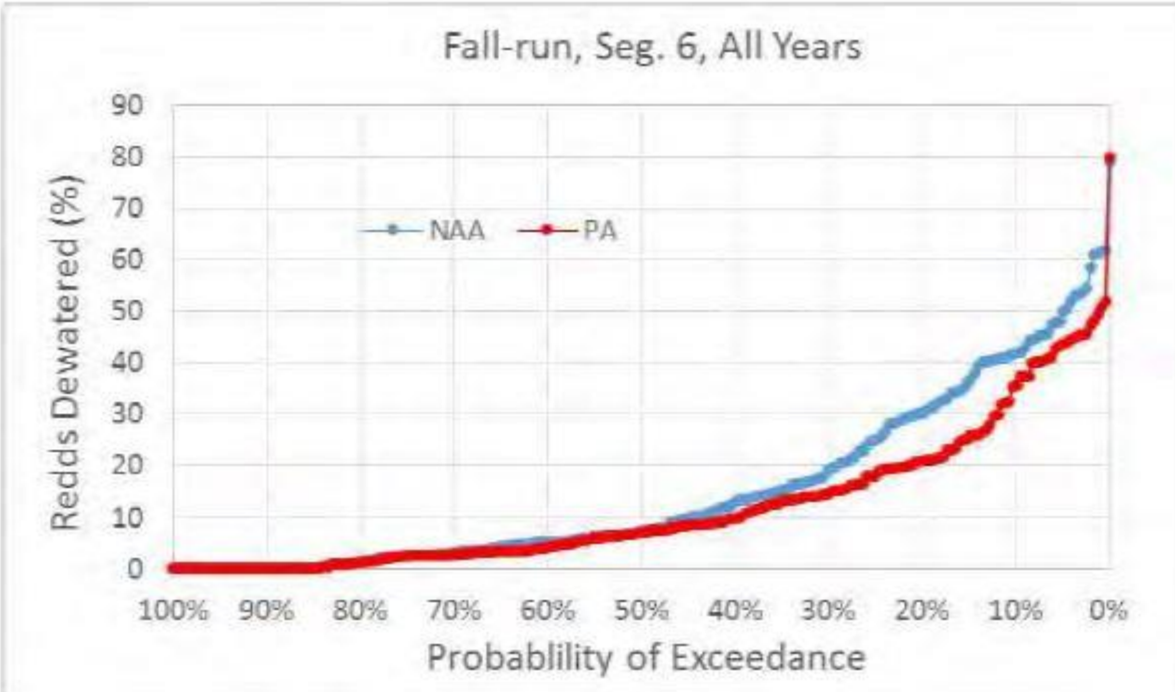
2.5.1.2.2.5.1.1 Fall-run Chinook Salmon

Fall-run Chinook salmon eggs and alevins in the Sacramento River are vulnerable to dewatering from the time when spawning begins in September through fry emergence in January (Vogel and Marine 1991). Nearly all fall-run Chinook salmon redds are constructed upstream of Woodson

Bridge, with 61 percent of redds occurring upstream of the Battle Creek confluence (**Error! Reference source not found.**). The redd dewatering analysis presented in the BA and below relies upon the relationships between flow fluctuations and redd dewatering for Chinook salmon in the Sacramento River between Keswick Dam and Battle Creek (U.S. Fish and Wildlife Service 2006). As such, the analysis covers the Sacramento River upstream of the Battle Creek confluence. Based on the spatial distribution of redds from 2003-2014 (Table 2-3), therefore, 60 percent of the habitat used for Sacramento River fall-run Chinook salmon spawning and egg incubation was analyzed for potential risks from dewatering, while the remaining 40 percent spawning habitat downstream of the Battle Creek confluence was not.

The percentage of fall-run Chinook salmon redds dewatered by reductions in Sacramento River flow was estimated using CALSIM II estimates of monthly mean flows during the three months following each month of spawning combined with the functional relationships developed in field studies by U.S. Fish and Wildlife Service (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows (BA Appendix 5D.2.2, *Spawning Flows Methods*). The analysis estimated fall-run Chinook salmon redd dewatering under the PA and NAA for the three upstream river segments (Segments 4, 5 and 6). River Segment 4 stretches 8 miles from Battle Creek to the confluence with Cow Creek; Segment 5 reaches 16 miles from Cow Creek to the A.C.I.D. Dam; and Segment 6 covers 2 miles from A.C.I.D. Dam to Keswick Dam. Detailed information on redd dewatering analysis methods is provided in the BA in Appendix 5D.2.2, *Spawning Flows Methods*.

Differences in fall-run Chinook salmon redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent of redds dewatered for the September through November months of spawning. Because river Segment 5 is the longest segment and includes the bulk of the analyzed fall-run Chinook salmon spawning area, those results are described in more detail here. The exceedance curves for the PA generally show consistently similar or lower redd dewatering percentages than those for the NAA for all water year types combined, and for wet and above normal water year types (Figure **Error! No text of specified style in document.**-53 through Figure **Error! No text of specified style in document.**-55). The biggest differences in the dewatering curves are predicted for wet water years, with about 61 percent of all months having greater than 20 percent of redds dewatered under the NAA, but only 40 percent of all months having greater than 20 percent of redds dewatered under the PA (Figure Error**! No text of specified style in document.**-54). Results for Segment 6 (Figure **Error! No text of specified style in document.**-47 through Figure **Error! No text of specified style in document.**-52) and Segment 4 (Figure **Error! No text of specified style in document.**-58 through Figure **Error! No text of specified style in document.**-64) are similar to those for Segment 5 (BA) in that the PA generally shows consistently similar or lower redd dewatering percentages than for the NAA for all water year types combined, and for wet and above normal water year types.



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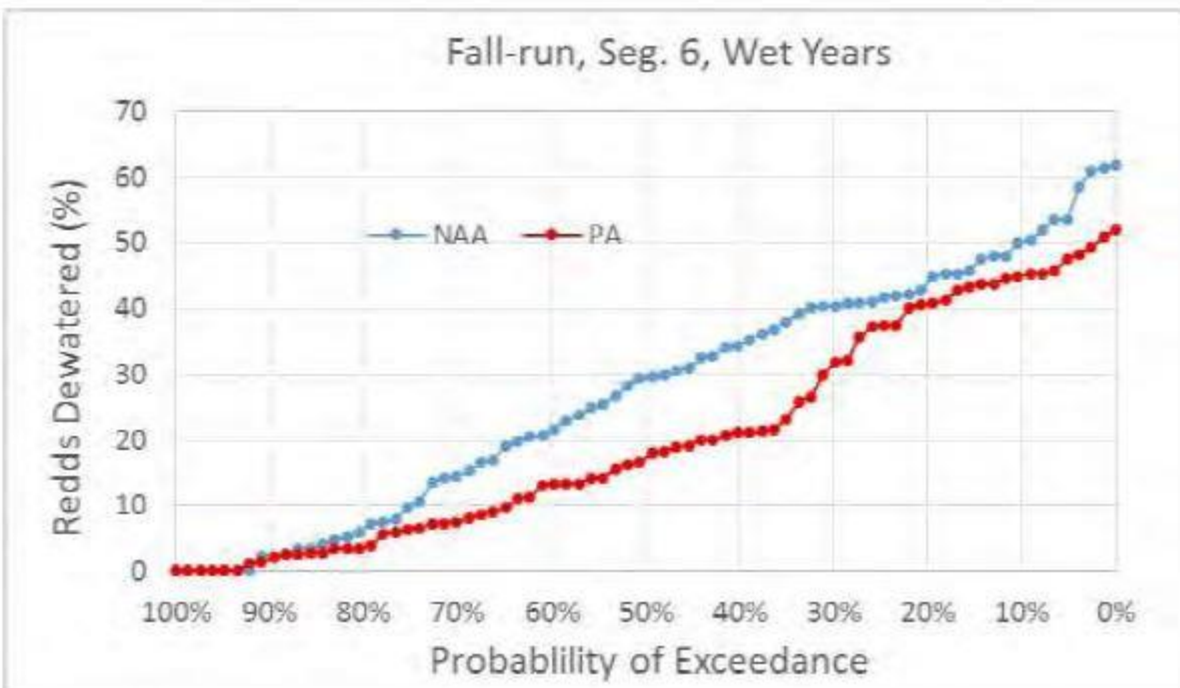

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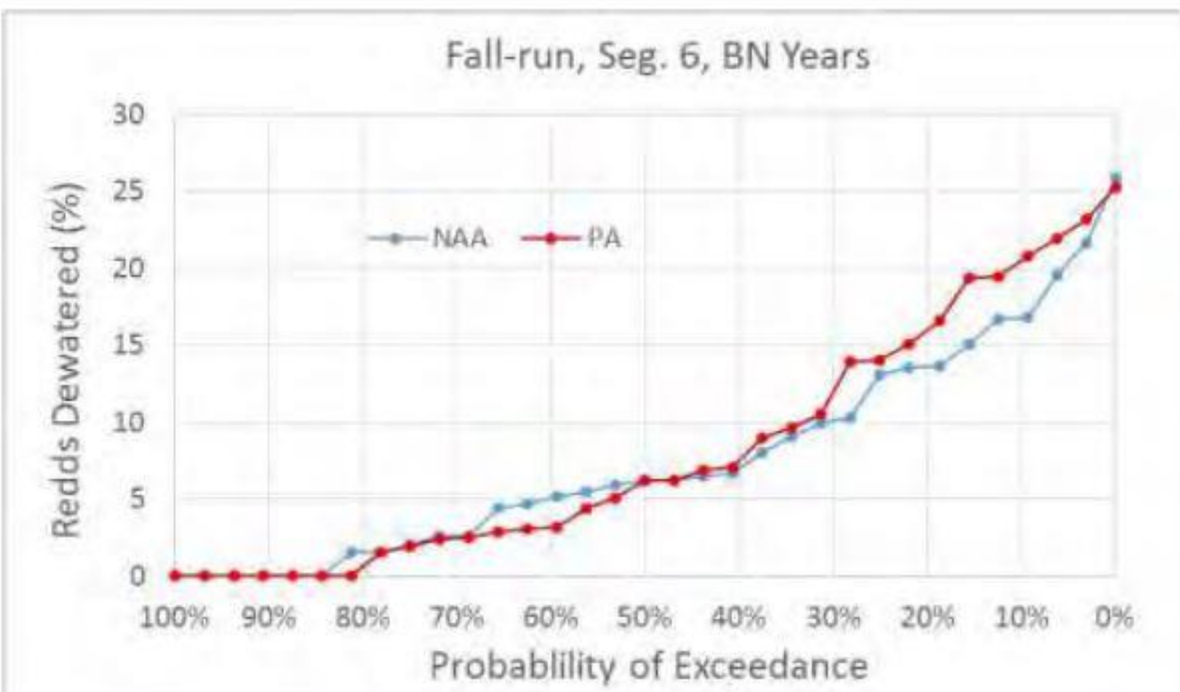

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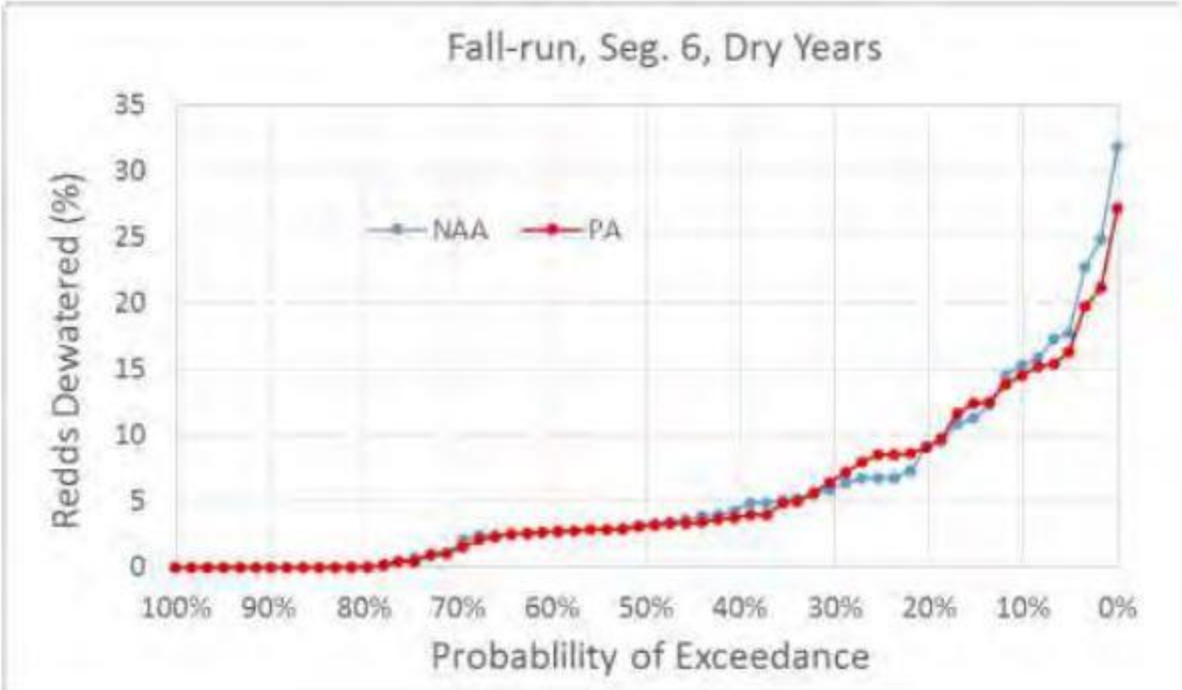

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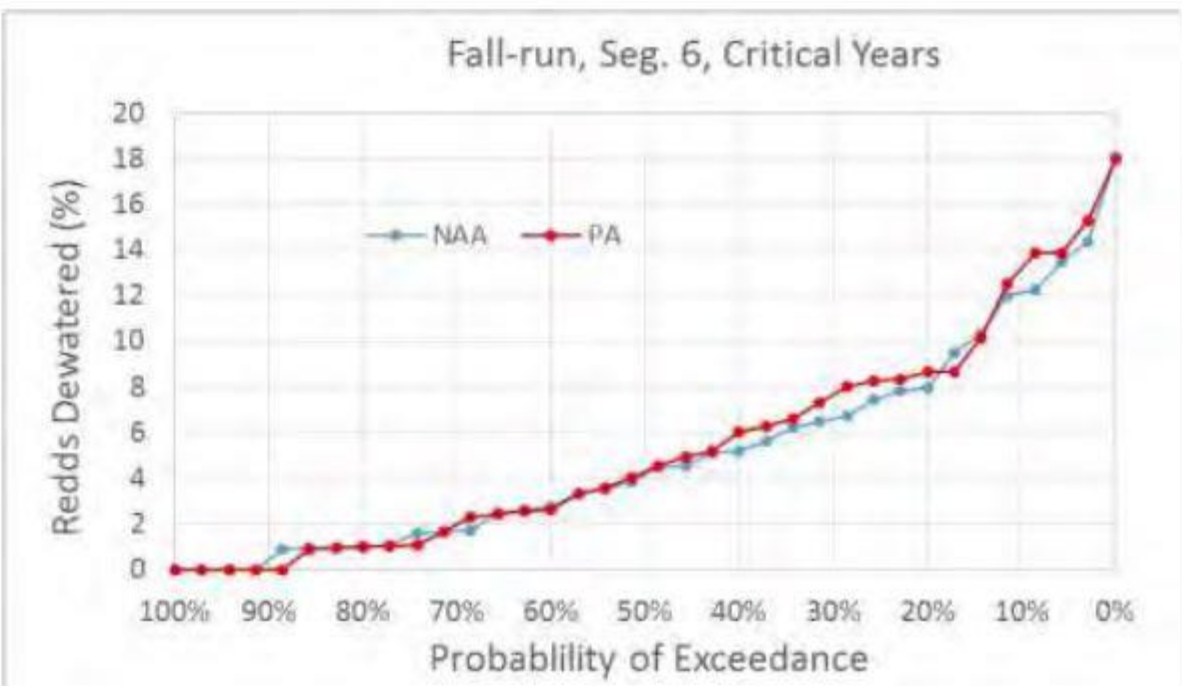

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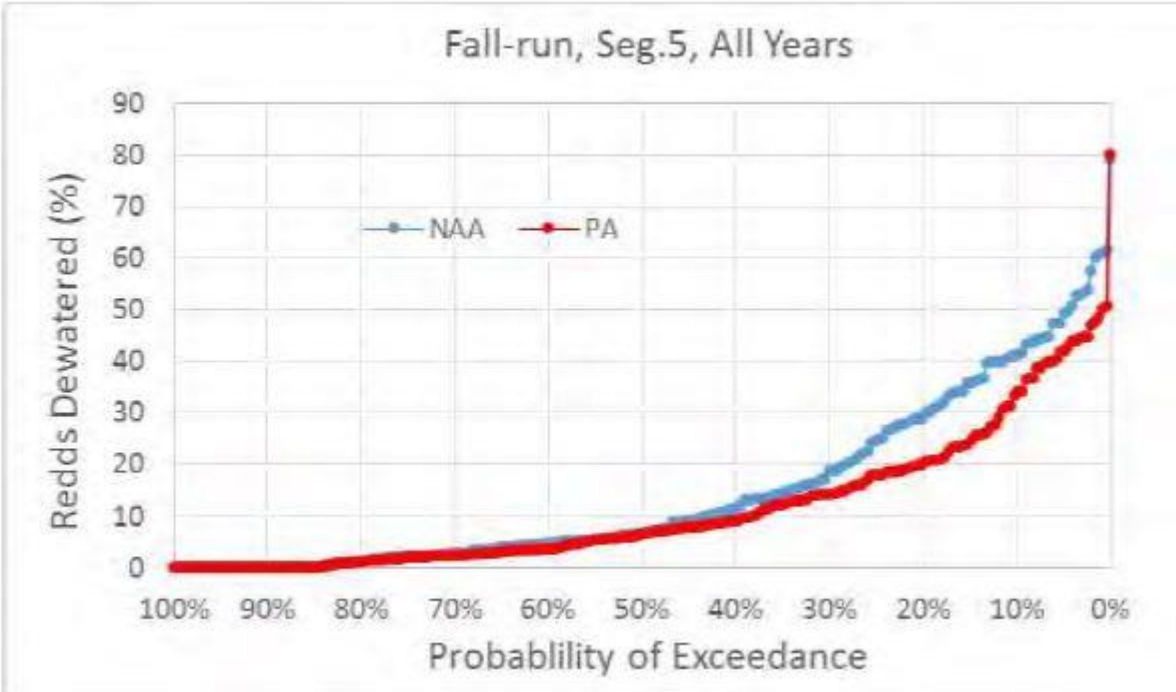

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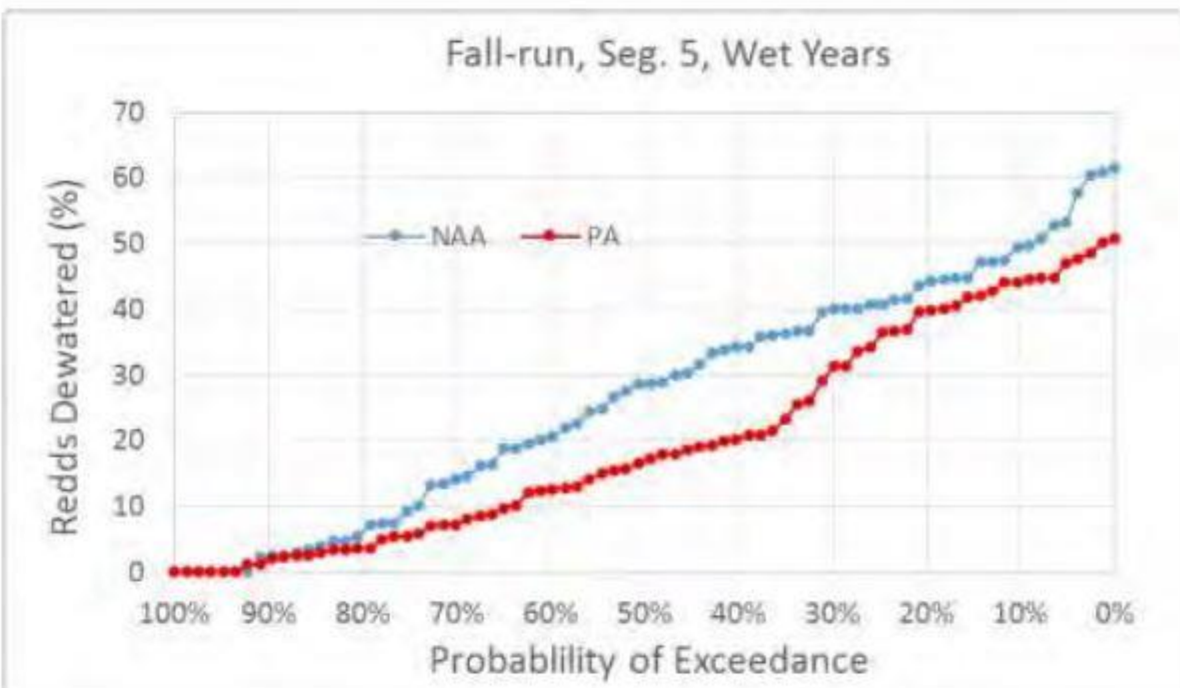

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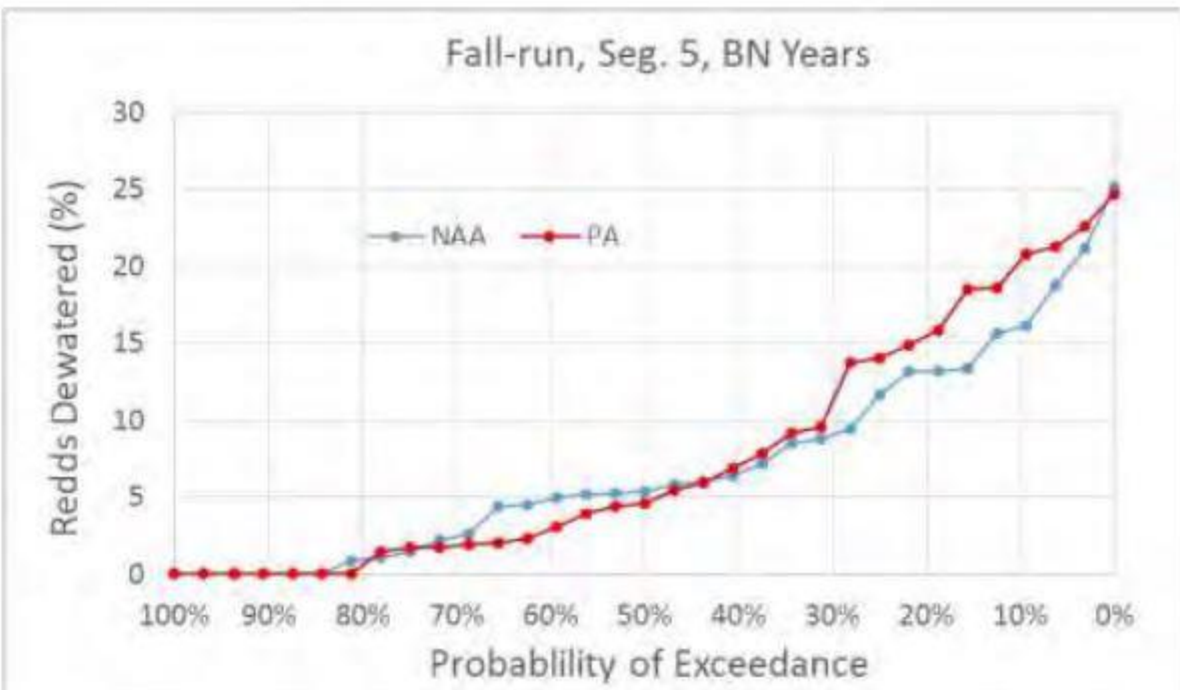

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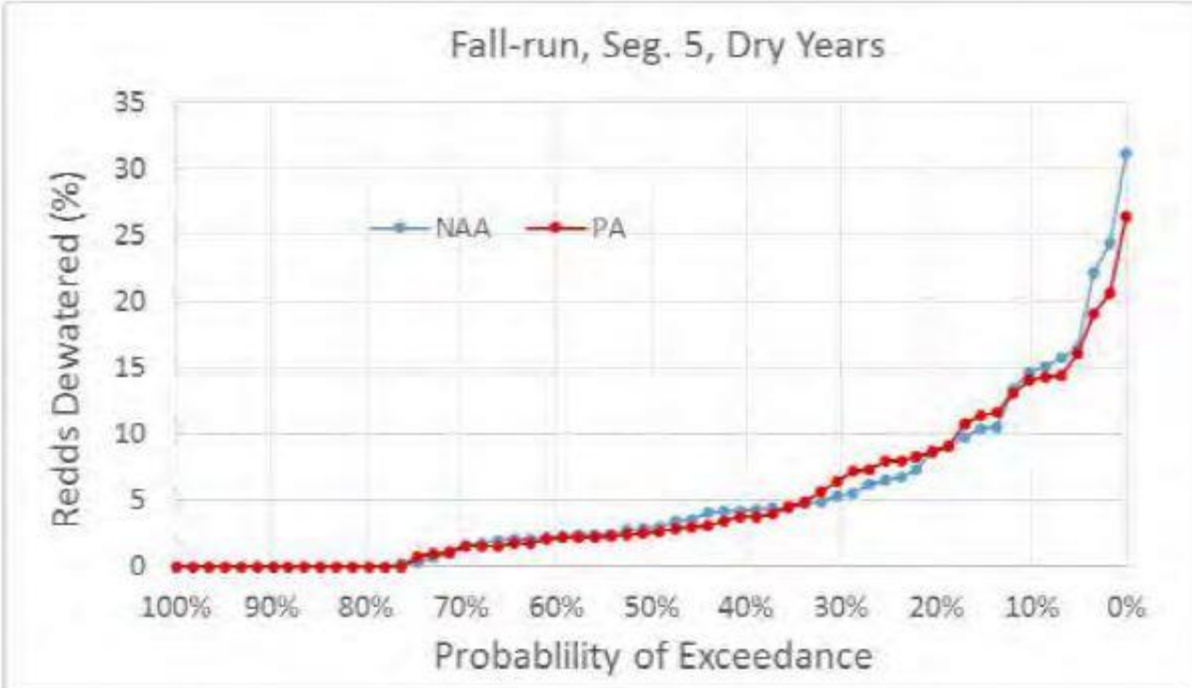

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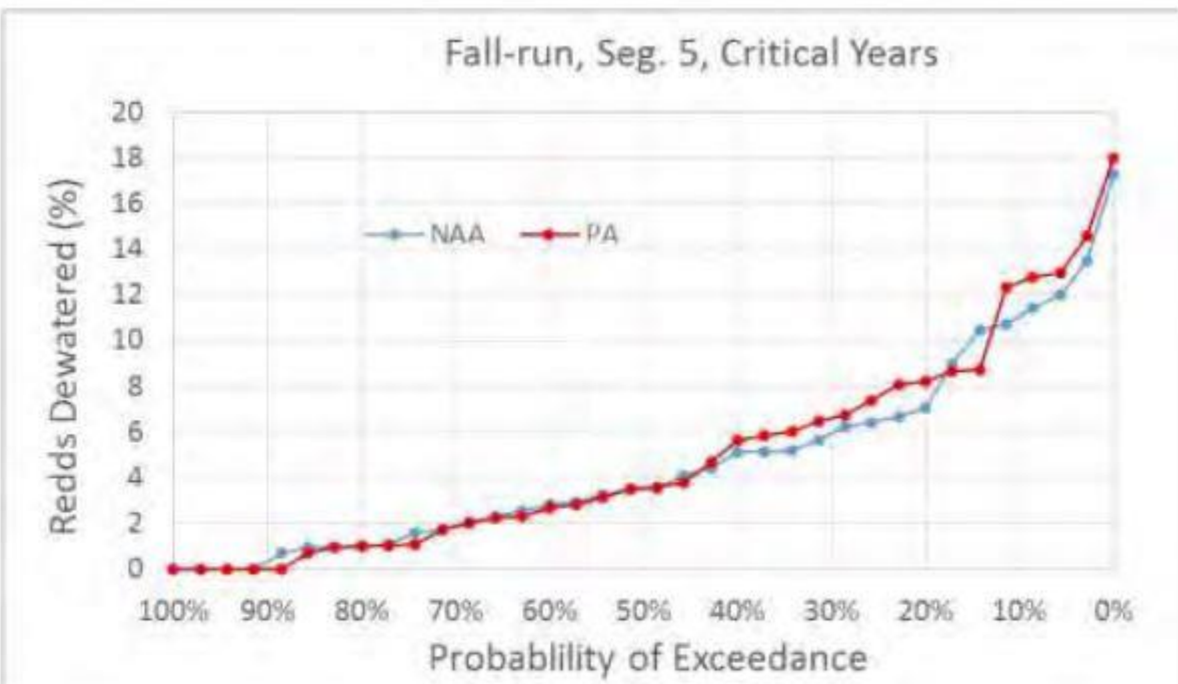

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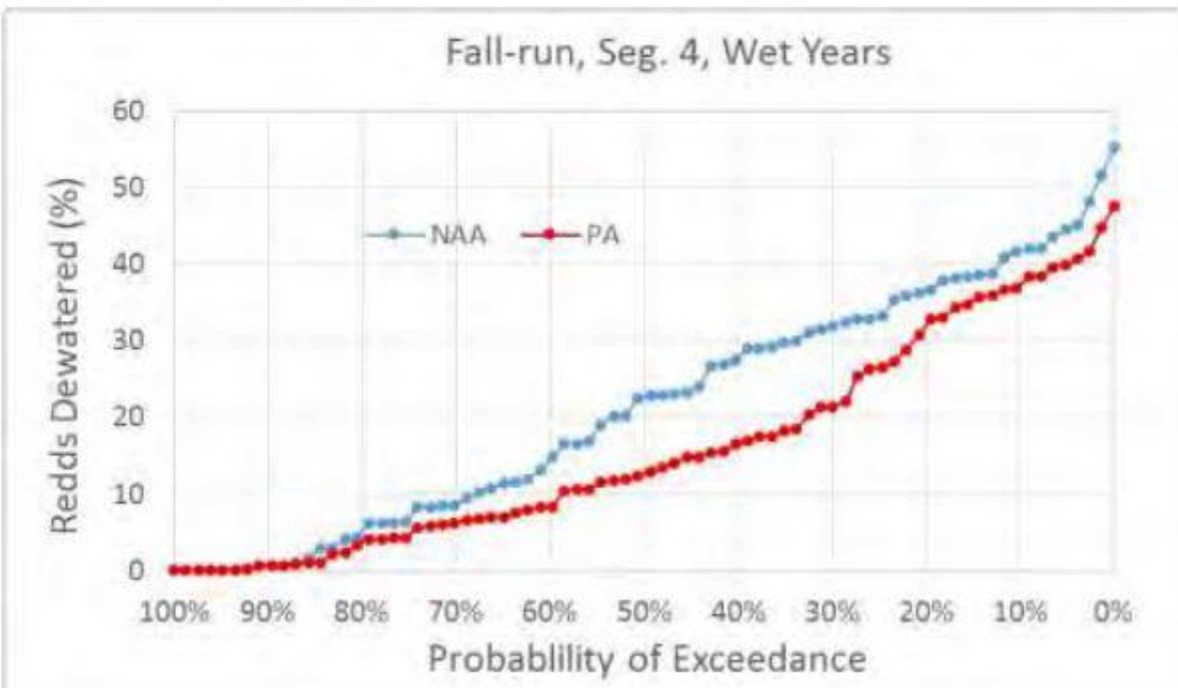

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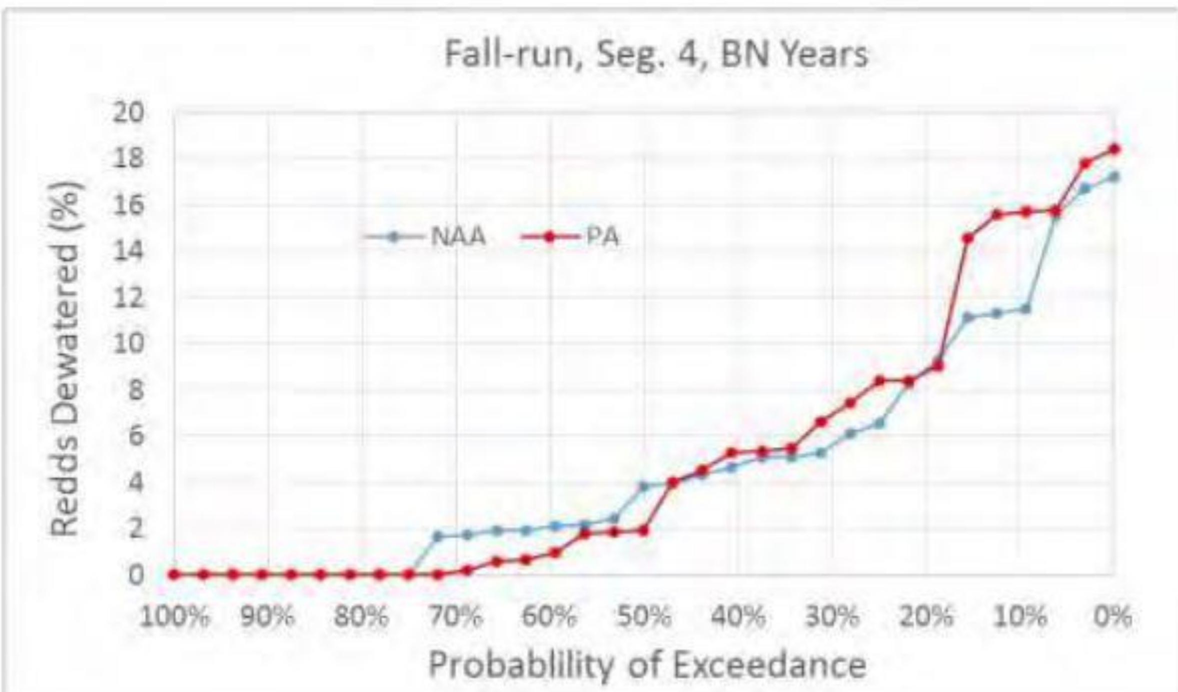

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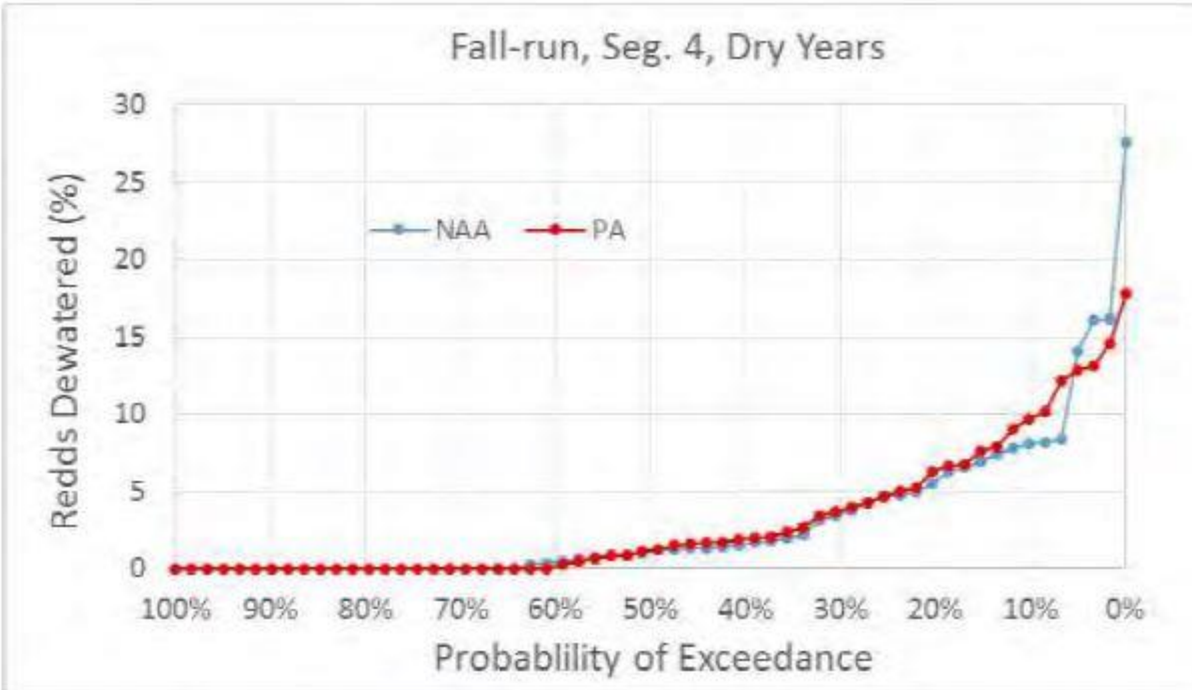

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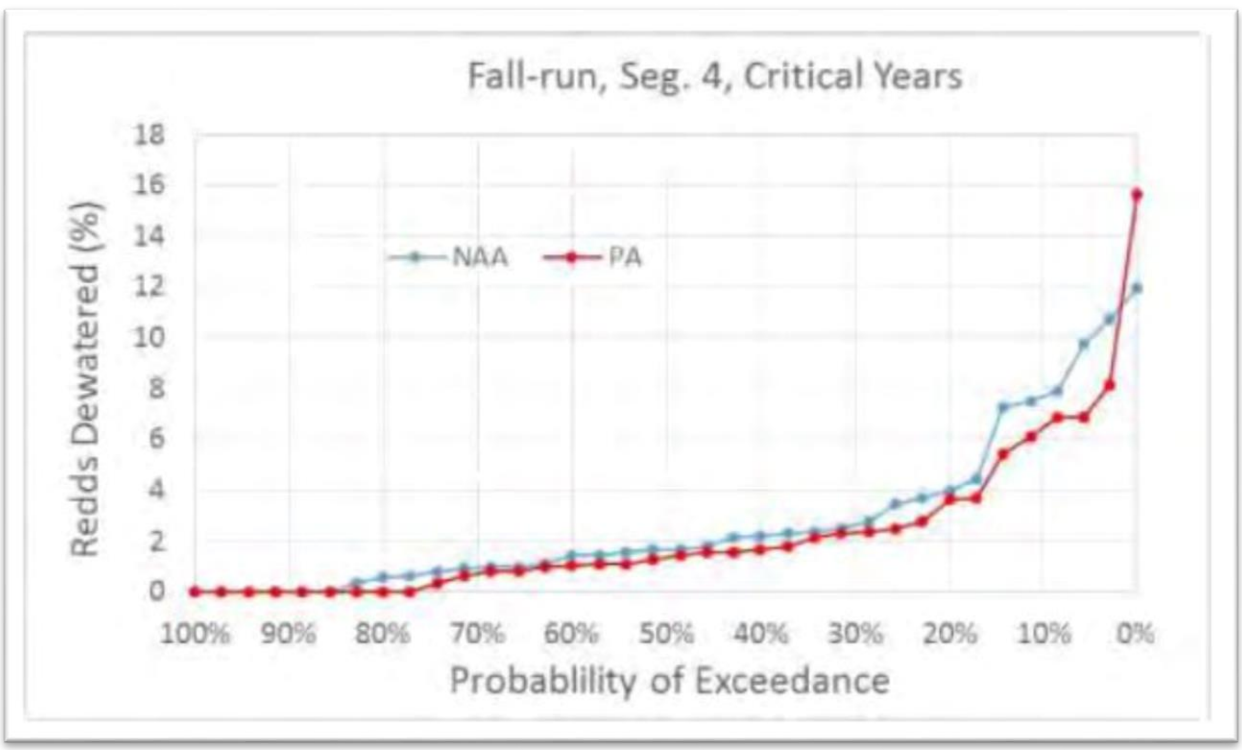

*Figure **Error! No text of specified style in document.**-64. Figure_5.E-95*

The exceedance curves show that the PA would not increase redd dewatering under most water year types relative to the NAA.

Tabular results from the BA show that differences between the PA and NAA in the mean percentage of redds dewatered in each river segment for each month of spawning under each water year type and all water year types combined would be minimal. The exception is moderate reductions in the mean percent of redds dewatered during November of wet and above normal water year types in all three river segments and a small increase in October of below normal years in river segments 5 and 6 (Table Error**! No text of specified style in document.**-26 through Table Error**! No text of specified style in document.**-27). The percent differences between the PA and the NAA in the percent of redds dewatered range up to a 208 percent increase under the PA for November of critical water years in Segment 4 (Table Error**! No text of specified style in document.**-28). However, this increase and most of the large relative changes in percent of redds dewatered are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes.

Similar to the redd dewatering exceedance plots, the tabular results show little difference in redd dewatering risk between the PA and NAA, but the impact to fall-run Chinook salmon is a concern, particularly in wet years. During November of wet years, the percentage of dewatered redds ranges between 15 and 36 percent across all river segments for the PA. Redd dewatering under the PA in November of dry years is much lower compared to wet years, ranging between just three and five percent.

*Table **Error! No text of specified style in document.**-26. Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 6 between Model Scenarios (green indicates PA is at least 5 percent lower [raw difference] than NAA; red indicates PA is at* least 5 percent higher)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	31.1	33.0	2 (6%)
	Above Normal	19.0	17.7	-1.25 (-7%)
	Below Normal	6.5	3.4	-3 (-47%)
	Dry	3.9	2.6	-1.3 (-33%)
	Critical	6.9	5.3	-1.6 (-24%)
September	All	15.7	15.2	-0.5 (-3%)
October	Wet	15.0	10.3	-4.7 (-32%)
	Above Normal	13.0	13.6	0.7 (5%)
	Below Normal	9.5	15.9	6.4 (67%)
	Dry	8.2	10.3	2.1 (25%)
	Critical	7.0	6.4	-0.6 (-8%)
	All	11.1	11.0	-0.1 (-1%)
November	Wet	35.9	18.7	-17.2 (-48%)
	Above Normal	33.9	15.2	-18.7 (-55%)
	Below Normal	7.2	5.4	-1.8 (-25%)
	Dry	4.7	3.2	-1.5 (-31%)
	Critical	1.6	4.5	2.9 (176%)
	All	18.9	10.4	-8.5 (-45%)

*Table **Error! No text of specified style in document.**-27. Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 5 between Model Scenarios (green indicates PA is at least 5 percent lower [raw difference] than NAA; red indicates PA is at least 5 percent higher)*

Month	WYT	NAA	PA	PA vs. NAA
	Wet	30.2	31.9	1.7 (6%)
	Above Normal	17.9	16.5	-1.5 (-8%)
	Below Normal	5.6	2.7	-2.9 (-52%)
	Dry	3.1	1.9	-1.2 (-38%)
	Critical	6.0	4.4	-1.6 (-26%)
September	All	14.8	14.2	-0.6 (-4%)
October	Wet	14.5	9.9	-4.6 (-32%)
	Above Normal	12.4	13.1	0.6 (5%)
	Below Normal	9.1	15.4	6.3 (70%)
	Dry	7.9	9.9	2 (26%)
	Critical	6.7	6.1	-0.6 (-9%)
	All	10.7	10.6	-0.1 (-1%)
November	Wet	35.6	18.5	-17.1 (-48%)
	Above Normal	33.7	15.2	-18.5 (-55%)
	Below Normal	7.0	5.2	-1.8 (-25%)
	Dry	4.7	3.3	-1.4 (-30%)
	Critical	1.6	4.5	2.9 (178%)
	All	18.8	10.4	-8.4 (-45%)

Table ***Error! No text of specified style in document.****-28. Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 4 between Model Scenarios (green indicates PA is at least 5 percent lower [raw difference] than NAA; red indicates PA is at least 5 percent higher)*

Month	WYT	NAA	PA	PA vs. NAA
	Wet	24.9	26.5	1.6 (6%)
	Above Normal	13.5	12.2	-1.39 (-10%)
	Below Normal	3.1	1.2	-1.9 (-63%)
	Dry	1.0	0.6	-0.4 (-37%)
	Critical	3.5	1.7	-1.8 (-51%)
September	All	11.2	10.9	-0.3 (-3%)
October	Wet	9.3	6.6	-2.7 (-29%)
	Above Normal	8.9	10.0	1.1 (12%)
	Below Normal	6.4	10.9	4.4 (69%)
	Dry	5.0	6.2	1.3 (25%)
	Critical	4.0	2.8	-1.3 (-31%)
	All	7.0	7.0	0 (0%)
November	Wet	29.8	15.3	-14.5 (-49%)
	Above Normal	28.2	12.6	-15.6 (-55%)
	Below Normal	5.1	3.5	-1.6 (-31%)
	Dry	3.4	2.5	-0.9 (-27%)
	Critical	0.8	2.6	1.7 (208%)
	All	15.4	8.2	-7.2 (-46%)

Another source of information suggesting that redd dewatering in the Sacramento River is a concern under the PA overall and especially in wet years comes from the SALMOD results presented in the BA (Table **Error! No text of specified style in document.**-29). The SALMOD model provides predicted flow-related mortality of fall-run Chinook salmon spawning, eggs and alevins in the Sacramento River. The SALMOD results for flow-related mortality are presented in Table **Error! No text of specified style in document.**-29. The flow-related mortality of fall-run Chinook salmon spawning, eggs, and alevins is divided into “incubation” (which refers to redd dewatering and scour) and “superimposition” (which refers to redd overlap) mortality (see Attachment 5.D.2, SALMOD Model). The number of fall-run Chinook salmon eggs and alevins predicted to die from redd dewatering and scour during incubation ranges from 94,913 in above normal years to 4,066,702 in wet years, with an average over all water year types of 1,477,164 (Reclamation 2016).

*Table **Error! No text of specified style in document.**-29. Mean Annual Fall-Run Chinook Salmon Mortality1 (# of Fish/Year) Predicted by SALMOD*

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing										
	Temperature-Related Mortality			Flow-Related Mortality				Temperature-Related Mortality				Flow-Related Mortality						
Analysis Period	Pre-Spawn	Eggs	Subtotal	Incubation	Super-imposition	Subtotal	Life Stage Total	Fry	Pre-smolt	Immature Smolt	Subtotal	Fry	Pre-smolt	Immature Smolt	Subtotal	Life Stage Total	Grand Total
All Water Year Types[1]																	
NAA	5,144,855	809,484	5,954,338	1,451,660	511,012	1,962,672	7,917,010	150	4,296	6,055	10,501	4,694,051	266,976	40,366	5,001,393	5,011,894	12,928,904
PA	5,022,884	660,993	5,683,877	1,477,164	550,222	2,027,386	7,711,263	160	3,305	5,350	8,814	4,716,470	267,867	41,632	5,025,968	5,034,783	12,746,046
Difference	-121,970	-148,491	-270,461	25,504	39,210	64,714	-205,747	10	-991	-705	-1,687	22,419	891	1,265	24,575	22,889	-182,859
Percent Difference[3]	-2	-18	-5	2	8	3	-3	6	-23	-12	-16	0	0	3	0	0	-1
Water Year Types[2]																	
Wet (32.5%)																	
NAA	224,282	724,794	949,076	4,013,334	1,304,607	5,317,941	6,267,017	419	4,344	1,216	5,980	5,142,369	77,086	14,964	5,234,419	5,240,399	11,507,415
PA	81,977	213,648	295,625	4,066,702	1,436,450	5,503,152	5,798,777	472	4,231	1,943	6,645	5,194,728	75,562	16,386	5,286,676	5,293,321	11,092,098
Difference	-142,305	-511,146	-653,451	53,368	131,843	185,212	-468,240	52	-113	726	666	52,359	-1,525	1,422	52,256	52,922	-415,318
Percent Difference	-63	-71	-69	1	10	3	-7	13	-3	60	11	1	-2	10	1	1	-4
Above Normal (12.5%)																	
NAA	9,090,676	497,965	9,588,640	63,475	688,815	752,290	10,340,930	20	2,720	987	3,726	5,001,065	116,203	25,093	5,142,361	5,146,087	15,487,018
PA	9,476,226	106,985	9,583,211	94,913	675,539	770,452	10,353,663	19	2,397	1,086	3,502	5,134,558	124,860	26,228	5,285,646	5,289,147	15,642,810
Difference	385,550	-390,980	-5,430	31,439	-13,276	18,162	12,732	-1	-322	99	-224	133,493	8,656	1,135	143,284	143,060	155,792
Percent Difference	4	-79	0	50	-2	2	0	-5	-12	10	-6	3	7	5	3	3	1
Below Normal (17.5%)																	
NAA	57,594	127,629	185,223	306,984	0	306,984	492,207	0	571	872	1,443	5,201,156	404,885	55,474	5,661,515	5,662,958	6,155,165
PA	57,234	124,986	182,221	303,758	0	303,758	485,979	0	514	911	1,426	5,188,265	397,816	61,171	5,647,252	5,648,678	6,134,656
Difference	-360	-2,643	-3,003	-3,226	0	-3,226	-6,228	0	-56	39	-18	-12,890	-7,070	5,697	-14,263	-14,281	-20,509
Percent Difference	-1	-2	-2	-1	0	-1	-1	0	-10	4	-1	0	-2	10	0	0	0
Dry (22.5%)																	
NAA	4,432,070	732,312	5,164,382	364,687	0	364,687	5,529,069	65	2,706	1,662	4,434	4,607,491	443,967	57,263	5,108,721	5,113,155	10,642,224
PA	4,421,190	1,145,829	5,567,018	374,597	0	374,597	5,941,615	38	1,957	841	2,837	4,464,993	455,957	56,178	4,977,128	4,979,965	10,921,580
Difference	-10,880	413,517	402,637	9,910	0	9,910	412,546	-27	-749	-821	-1,597	-142,498	11,990	-1,086	-131,593	-133,190	279,356
Percent Difference	0	56	8	3	0	3	7	-41	-28	-49	-36	-3	3	-2	-3	-3	3
Critical (15%)																	
NAA	17,301,522	2,051,093	19,352,615	363,933	0	363,933	19,716,548	0	11,836	33,277	45,112	3,132,461	391,949	66,552	3,590,961	3,636,073	23,352,621
PA	16,417,771	1,830,250	18,248,020	377,779	0	377,779	18,625,799	0	7,087	28,295	35,382	3,288,656	378,908	67,477	3,735,041	3,770,423	22,396,222
B Difference	-883,752	-220,843	-1,104,595	13,846	0	13,846	-1,090,749	0	-4,748	-4,982	-9,730	156,195	-13,040	926	144,080	134,350	-956,399
Percent Difference	-5	-11	-6	4	0	4	-6	0	-40	-15	-22	5	-3	1	4	4	-4

1 Mortality values do not include base mortality
2 Based on the 80-year simulation period
3 Relative difference of the Annual average
4 As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB 1995). Water years may not correspond to the biological years in SALMOD.
5 NA = Unable to calculate because dividing by 0

Collectively, the estimated percentage of redd dewatering presented in the exceedance plots (Figure **Error! No text of specified style in document.**-47 through Figure **Error! No text of specified style in document.**-64) and tables (Tables 5.E-34 through 5.E-36) indicate that Sacramento River redd dewatering under the PA is a high magnitude stressor to fall-run Chinook salmon in wet years and a medium stressor under relatively dry conditions. The SALMOD results show that the combined effect of redd dewatering and scour under the PA places a high magnitude stress on fall-run Chinook salmon in the Sacramento River. The certainty of these magnitude rankings is medium given the limitations of using results based on monthly flows to understand the magnitude of impacts that occur over daily time scale.

2.5.1.2.2.5.1.2 Late Fall-run Chinook Salmon

Late fall-run Chinook salmon eggs and alevins in the Sacramento River are vulnerable to dewatering from the time when spawning begins in December through April (Vogel and Marine 1991). The vast majority of late fall-run Chinook salmon redds are distributed in the upper portion of the Sacramento River, with 68 percent occurring upstream of ACID Dam and 94 percent occurring upstream of Red Bluff Diversion Dam (BA Table 5.D.1-1 in Appendix 5D Attachment 1).

The percentage of late fall-run Chinook salmon redds dewatered by reductions in Sacramento River flow was estimated from CALSIM II estimates of monthly mean flows during the 3 months following each month of spawning (BA Appendix 5.D.2.2, Spawning Flows, Methods, Table 5-4-2). This analysis employed functional relationships developed in field studies by USFWS (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows. CALSIM II flows for the three upstream river segments (segments 4, 5 and 6) were used to estimate redd dewatering under the PA and NAA. Note that unlike the analyses used to model weighted usable area, the analysis used to model redd dewatering combines the field observations of water depth, flow velocity, and substrate from the three river segments and, therefore, differences in redd dewatering estimates among the segments result only from differences in the CALSIM II flows. Further information on redd dewatering analysis methods is provided in the BA in Appendix 5.D.2.2, Spawning Flows, Methods.

Differences in late fall-run Chinook salmon redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent dewatered for the December through April spawning months (see Figures 5.E-168 through 5.E-185 in the BA). Because 67 percent of late fall-run Chinook salmon spawning occurs in river Segment 6 and the results for segments 4 and 5 are similar to those for Segment 6, conclusions regarding effects are primarily based on the Segment 6 results (Figure 5.E-168 through Figure 5E-173). The exceedance curves show little difference between the PA and the NAA in the percentage of redds dewatered for all water years combined or for individual water year types, except for marginally greater redd dewatering under the PA for wet years (Figure 5.E-169).

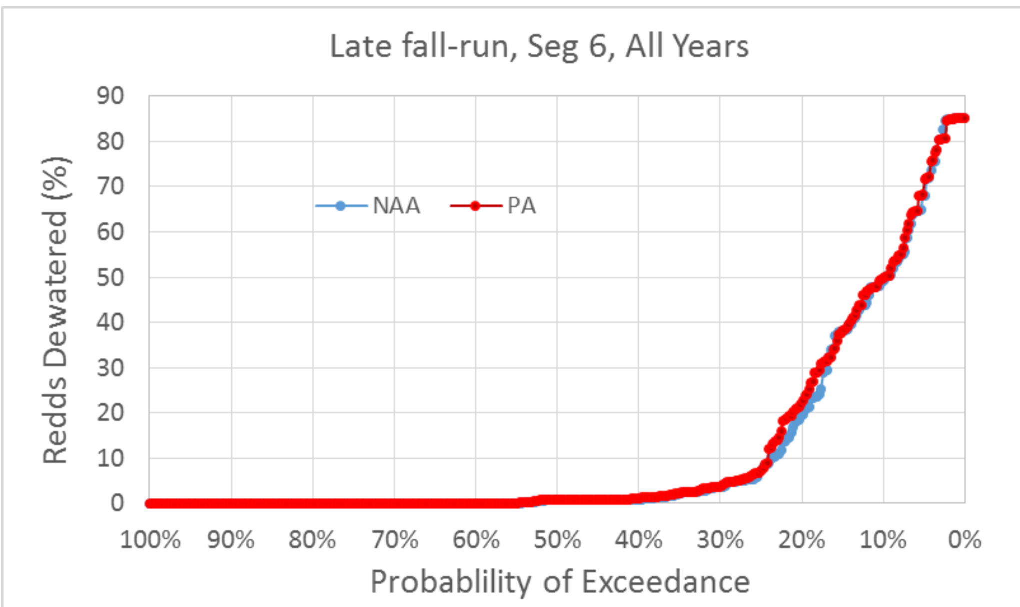

*Figure **Error! No text of specified style in document.**-65. Figure 5.E-168. Exceedance Plot of Late Fall-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, All Water Years.*

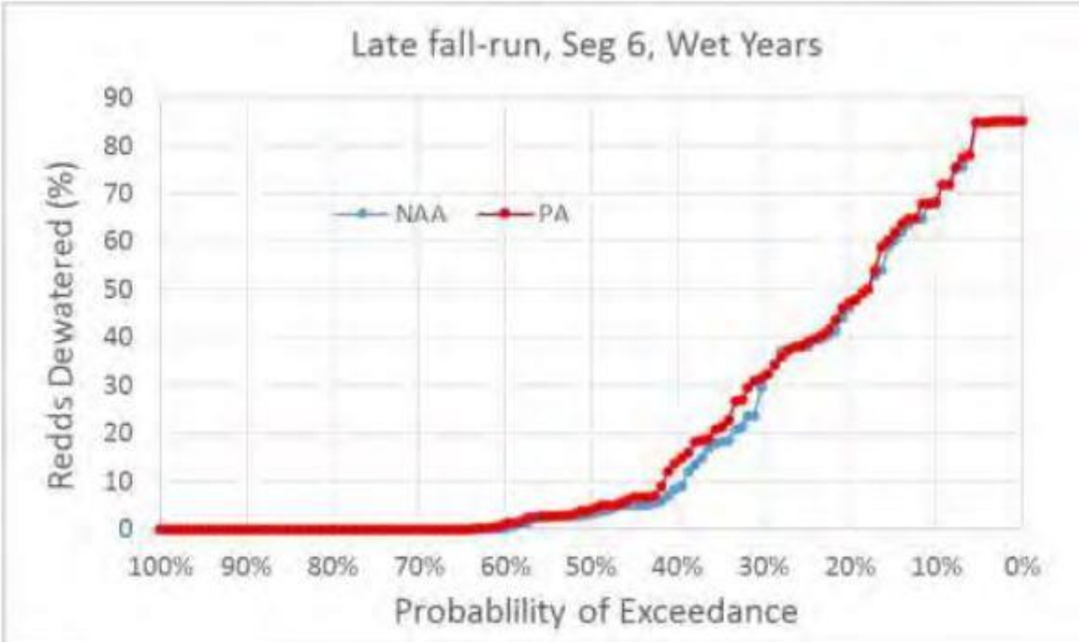

*Figure **Error! No text of specified style in document.**-66. Figure 5.E-169. Exceedance Plot of Late Fall-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Wet Water Years.*

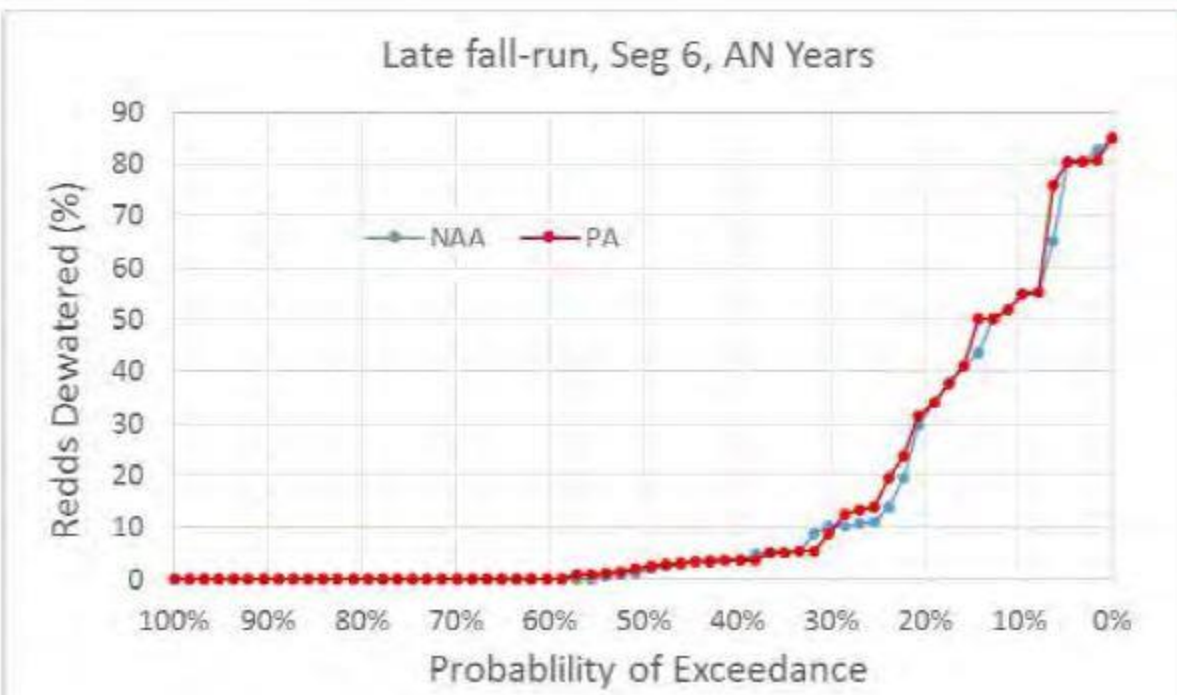

*Figure **Error! No text of specified style in document.**-67. Figure 5.E-170. Exceedance Plot of Late Fall-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years.*

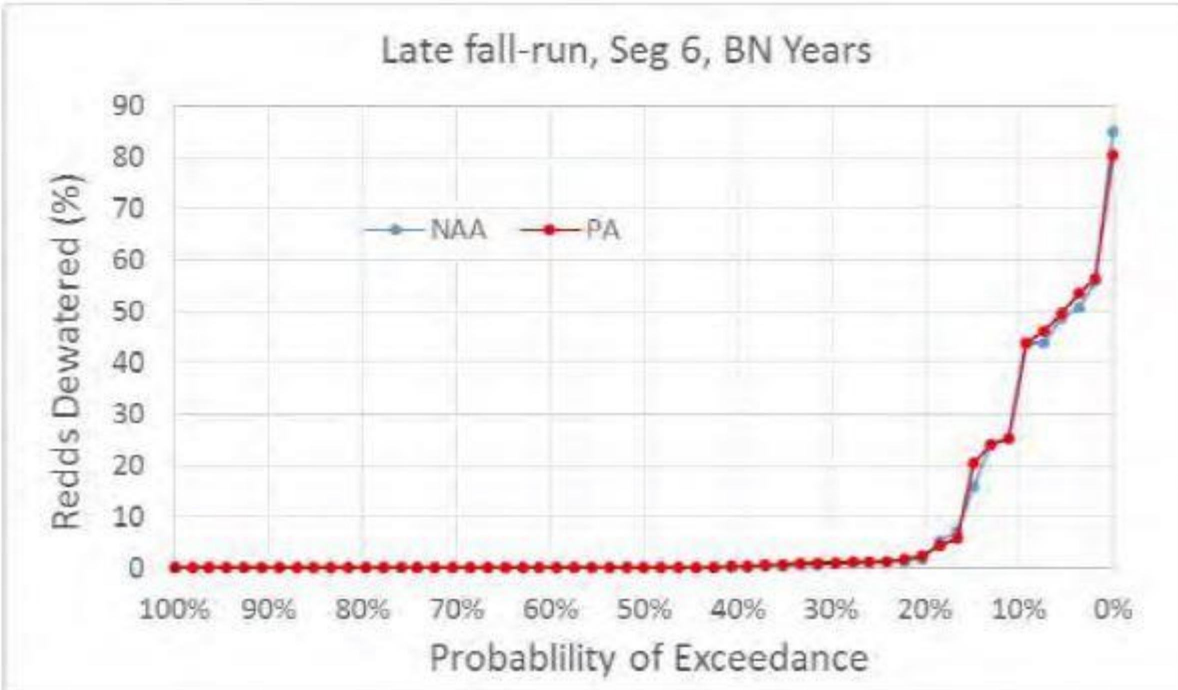

*Figure **Error! No text of specified style in document.**-68. Figure 5.E-171. Exceedance Plot of Late Fall-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years.*

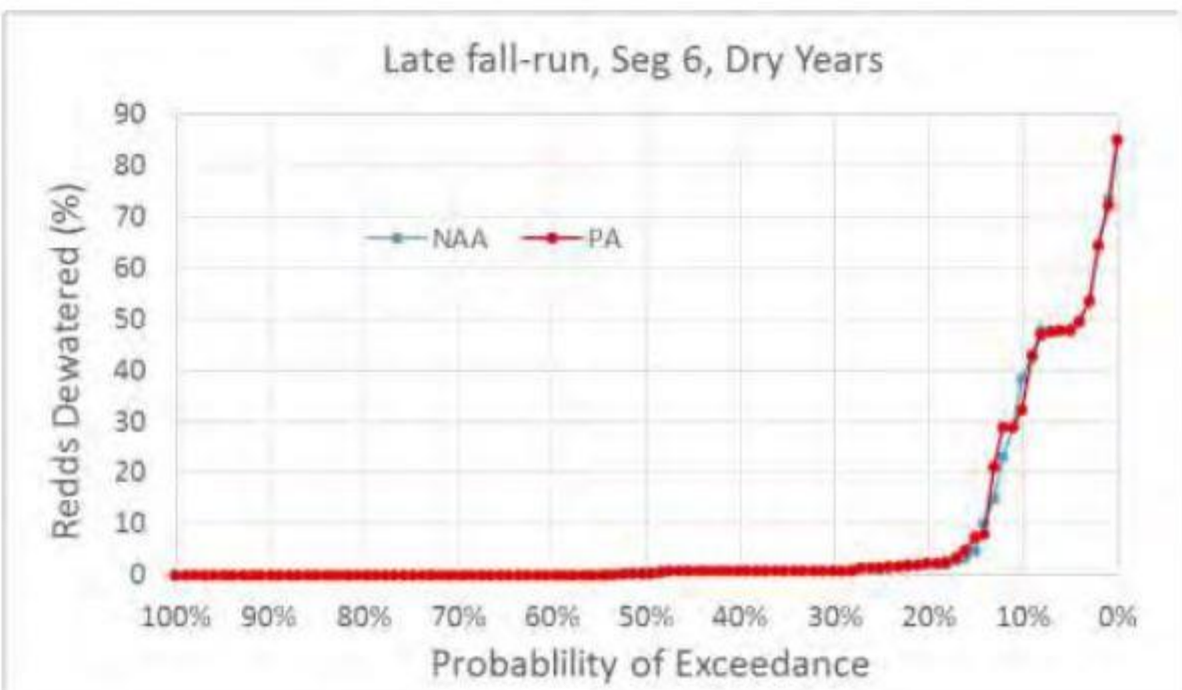

*Figure **Error! No text of specified style in document.**-69. Figure 5.E-172. Exceedance Plot of Late Fall-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Dry Water Years.*

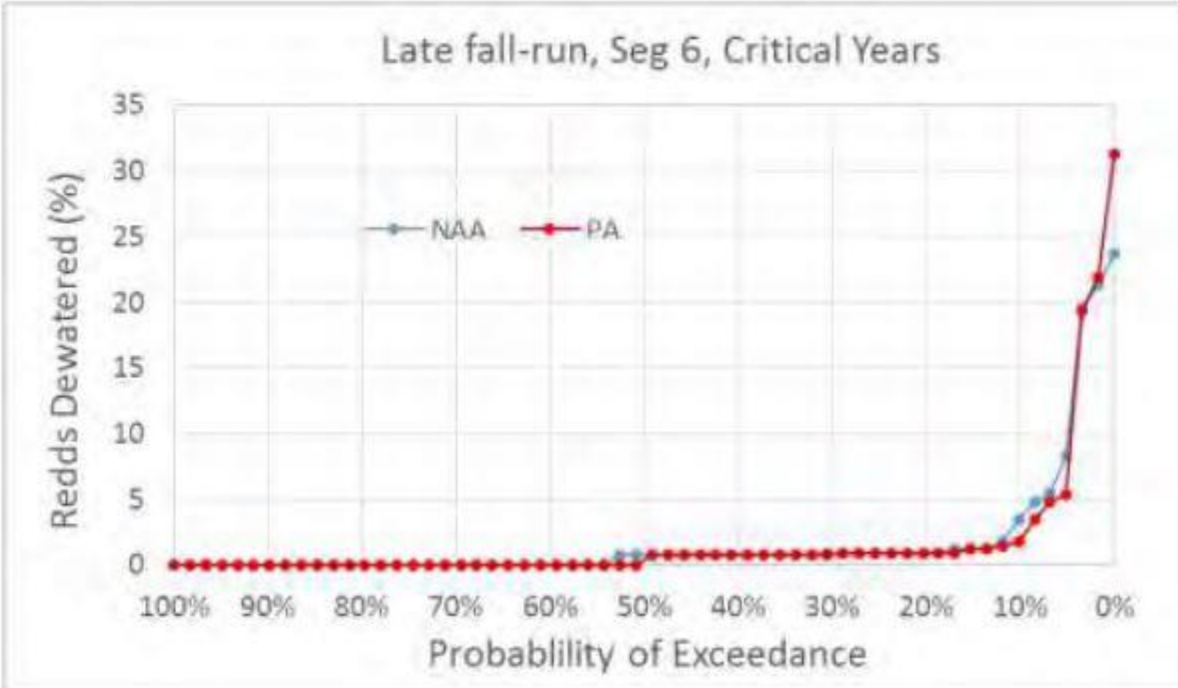

Figure ***Error! No text of specified style in document.****-70. Figure 5.E-173. Exceedance Plot of Late Fall-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Critical Water Years.*

The exceedance curves show that the PA would not increase redd dewatering under most water year types relative to the NAA.

The following description and tabular results from the BA show that differences between the PA and NAA in the mean percentage of late fall-run Chinook salmon redds dewatered in each river segment for each month of spawning under each water year type and all water year types combined would minimal (Tables 5.E-51 through 5.E-53). The percent of redds dewatered under the PA was little different from that under the NAA for all months and water year types, ranging up to 2.9 percent greater under the PA for January of wet years in Segment 5 (Table 5.E-52). The percent differences in the percent of redds dewatered between the PA and the NAA range up to a 130 percent increase under the PA for January of critical water years in Segment 6 (Table 5.E-51), but this increase and the other large relative changes in percent of redds dewatered are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent differences.

Similar to the redd dewatering exceedance plots, the tabular results show little difference between the PA and NAA, but the impact to late fall-run Chinook salmon is a concern, particularly in wet and above normal years. During February of wet and above normal years under the PA the percentage of dewatered redds ranges between 37 percent and 39 percent across river segments 4, 5, and 6. Redd dewatering under the PA in February of dry years is much lower (than wet years) ranging between just 0.6 percent and 2 percent. However, the bulk of the redd dewatering in dry years occurs in January, with 17 percent to 18 percent of all redds being dewatered across river segments 4, 5, and 6.

*Table **Error! No text of specified style in document.**-30. Table 5.E-51. Late Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 6 between Model Scenarios (green indicates PA is at least 5 percent lower [raw difference] than NAA; red indicates PA is at least 5 percent higher)*

Month	WYT	NAA	PA	PA vs. NAA
	Wet	11.1	12.0	0.9 (8%)
	Above Normal	7.4	6.3	-1.1 (-15%)
	Below Normal	11.1	10.7	-0.4 (-3%)
	Dry	16.4	16.8	0.4 (2%)
	Critical	0.8	0.6	-0.2 (-22%)
December	All	10.3	10.5	0.1 (1%)
January	Wet	18.7	21.5	2.8 (15%)
	Above Normal	11.3	11.4	0.1 (1%)
	Below Normal	11.3	10.9	-0.5 (-4%)
	Dry	16.9	17.2	0.4 (2%)
	Critical	2.1	4.8	2.7 (130%)
	All	13.7	15.0	1.3 (10%)
February	Wet	36.7	37.5	0.8 (2%)
	Above Normal	37.5	38.2	0.7 (2%)
	Below Normal	13.7	14.8	1 (7%)
	Dry	0.6	0.6	0.1 (10%)
	Critical	3.0	0.4	-2.6 (-87%)
	All	20.0	20.1	0.1 (1%)
March	Wet	29.0	28.9	-0.1 (-0.2%)
	Above Normal	13.6	16.1	2.5 (18%)
	Below Normal	1.4	2.1	0.6 (45%)
	Dry	1.5	1.3	-0.2 (-12%)
	Critical	0.1	0.1	0 (0%)
	All	11.9	12.4	0.4 (4%)
April	Wet	6.7	6.7	0 (0%)
	Above Normal	1.6	1.8	0.2 (11%)
	Below Normal	0.1	0.0	-0.1 (-69%)
	Dry	0.9	0.4	-0.4 (-50%)
	Critical	3.1	3.0	0 (-2%)
	All	3.1	3.0	-0.1 (-3%)

*Table **Error! No text of specified style in document.**-31. Table 5.E-52. Late Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 5 between Model Scenarios (green indicates PA is at least 5 percent lower [raw difference] than NAA; red indicates PA is at least 5 percent higher)*

Month	WYT	NAA	PA	PA vs. NAA
	Wet	11.1	12.0	0.9 (8%)
	Above Normal	7.5	6.5	-1.01 (-14%)
	Below Normal	11.0	10.6	-0.4 (-3%)
	Dry	16.5	16.8	0.3 (2%)
	Critical	0.8	0.7	-0.1 (-7%)
December	All	10.4	10.5	0.2 (2%)
January	Wet	18.8	21.7	2.9 (15%)
	Above Normal	11.5	11.6	0.1 (1%)
	Below Normal	11.4	10.9	-0.5 (-4%)
	Dry	17.0	17.3	0.3 (2%)
	Critical	2.2	5.0	2.8 (125%)
	All	13.8	15.1	1.4 (10%)
February	Wet	37.1	37.9	0.8 (2%)
	Above Normal	37.7	38.5	0.8 (2%)
	Below Normal	13.9	14.9	1 (7%)
	Dry	0.7	0.8	0.1 (14%)
	Critical	3.1	0.4	-2.7 (-86%)
	All	20.2	20.4	0.2 (1%)
March	Wet	29.6	29.6	-0.1 (-0.2%)
	Above Normal	14.0	16.5	2.6 (19%)
	Below Normal	1.5	2.2	0.7 (47%)
	Dry	1.7	1.5	-0.2 (-10%)
	Critical	0.1	0.1	0 (0.2%)
	All	12.2	12.7	0.5 (4%)
April	Wet	7.2	7.2	0 (-0.2%)
	Above Normal	1.7	1.9	0.2 (11%)
	Below Normal	0.1	0.0	-0.1 (-65%)
	Dry	0.9	0.5	-0.5 (-49%)
	Critical	3.0	3.0	-0.1 (-2%)
	All	3.2	3.1	-0.1 (-3%)

*Table **Error! No text of specified style in document.**-32. Table 5.E-53. Late Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 4 between Model Scenarios (green indicates PA is at least 5 percent lower [raw difference] than NAA; red indicates PA is at least 5 percent higher)*

Month	WYT	NAA	PA	PA vs. NAA
	Wet	11.1	12.2	1 (9%)
	Above Normal	6.9	6.5	-0.45 (-6%)
	Below Normal	10.4	10.4	0 (0%)
	Dry	17.4	17.6	0.1 (1%)
	Critical	1.4	1.4	-0.1 (-4%)
December	All	10.5	10.8	0.3 (3%)
January	Wet	19.1	21.7	2.6 (13%)
	Above Normal	11.9	12.0	0 (0%)
	Below Normal	13.9	13.3	-0.6 (-4%)
	Dry	17.3	17.7	0.4 (2%)
	Critical	3.4	6.1	2.7 (79%)
	All	14.6	15.8	1.2 (8%)
February	Wet	37.4	38.1	0.7 (2%)
	Above Normal	36.8	37.2	0.4 (1%)
	Below Normal	14.0	15.1	1.1 (8%)
	Dry	1.9	2.0	0.1 (5%)
	Critical	3.6	0.9	-2.7 (-74%)
	All	20.6	20.6	0.1 (0%)
March	Wet	28.5	28.4	-0.1 (-0.3%)
	Above Normal	14.9	17.4	2.6 (17%)
	Below Normal	1.5	2.4	0.8 (53%)
	Dry	3.2	2.8	-0.3 (-10%)
	Critical	0.5	0.5	0 (1.6%)
	All	12.4	12.9	0.4 (3%)
April	Wet	6.8	6.8	0 (-0.1%)
	Above Normal	2.0	2.2	0.2 (8%)
	Below Normal	0.2	0.1	-0.1 (-70%)
	Dry	1.1	0.7	-0.4 (-38%)
	Critical	2.5	2.4	-0.1 (-5%)
	All	3.1	3.0	-0.1 (-4%)

Collectively, the estimated percentage of redd dewatering presented in the exceedance plots (Figure **Error! No text of specified style in document.**-65 through Figure **Error! No text of specified style in document.**-70) and tables (Table **Error! No text of specified style in document.**-30 through Table **Error! No text of specified style in document.**-32) indicate that Sacramento River redd dewatering under the PA is a high magnitude stressor to late fall-run Chinook salmon in wet and above normal years and a medium stressor under dry conditions. The certainty of these magnitude rankings is medium given the limitations of using results based on monthly flows to understand the magnitude of impacts that occur over daily time scale.

2.5.1.2.2.5.2 American River

Fall-run Chinook salmon eggs and alevins in the American River are vulnerable to dewatering from the time when spawning begins in October through February (Vogel and Marine 1991; Bratovich et al. 2005). The vast majority of fall-run Chinook salmon spawning (i.e., 90 percent) in the American River occurs upstream between Ancil Hoffman Park at river mile 16 to Nimbus Dam at RM 3 (BA Table 5.D.1-4 in Appendix 5D Attachment 1).

The analysis of fall-run Chinook salmon redd dewatering for the American River relies on the analysis presented in the BA. In the BA, the percentage of fall-run Chinook salmon redds dewatered by reductions in American River flow was estimated from CALSIM II estimates of monthly mean flows during the 3 months following each of the months that fall-run Chinook salmon spawn (Section 5.D.2.2, Spawning Flow Methods, Table 5-4-2). No model for predicting percentages of redds dewatered, such as that developed for the Sacramento River (USFWS 2006), has been developed for the American River. Therefore, the maximum reduction in American River flow for the 3 months following each of the months during which fall-run Chinook salmon spawn was used as a proxy for percent of redds dewatered. CALSIM II flows at Nimbus were used for this analysis. Larger maximum flow reductions during the spawning, egg, and alevin life stages are assumed to increase the percent of redds dewatered and, therefore, to have a negative effect on fall-run Chinook salmon. Further information on the redd dewatering analysis is provided in the BA in Appendix 5.D.2.2, Spawning Flow Methods.

As described in the BA, differences in maximum flow reductions under the PA and NAA were examined using exceedance plots of mean monthly maximum flow reductions, expressed as a percentage of the spawning flows, for the months that American River fall-run Chinook salmon spawn (October and November) (Figure Error**! No text of specified style in document.**-71 through Figure Error**! No text of specified style in document.**-76). The exceedance curves for all water year types combined (Figure **Error! No text of specified style in document.**-71) and those for wet and above normal years (Figure **Error! No text of specified style in document.**-72 through Figure **Error! No text of specified style in document.**-73) indicate that the PA would generally have lower flow reductions than the NAA. Differences for the other three water year types would be minor (Figure **Error! No text of specified style in document.**-74 through Figure **Error! No text of specified style in document.**-76).

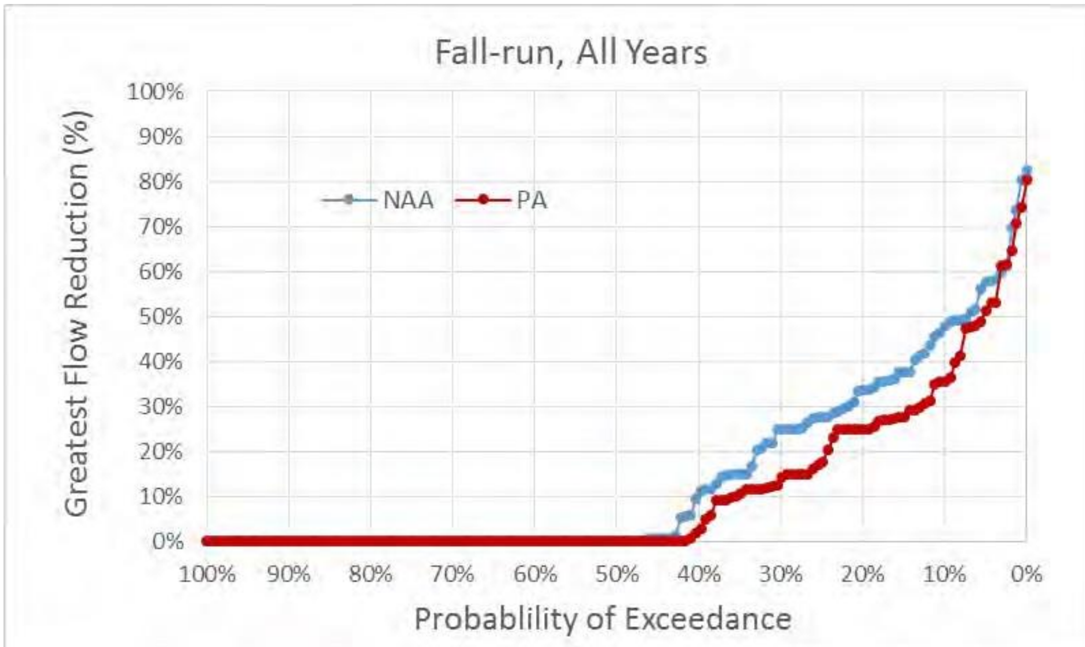

Figure ***Error! No text of specified style in document.****-71. Exceedance Plot of Maximum Flow Reductions (percent) for 3-Month Period after Fall-Run Chinook Salmon Spawning for NAA and PA Model Scenarios, All Water Years*

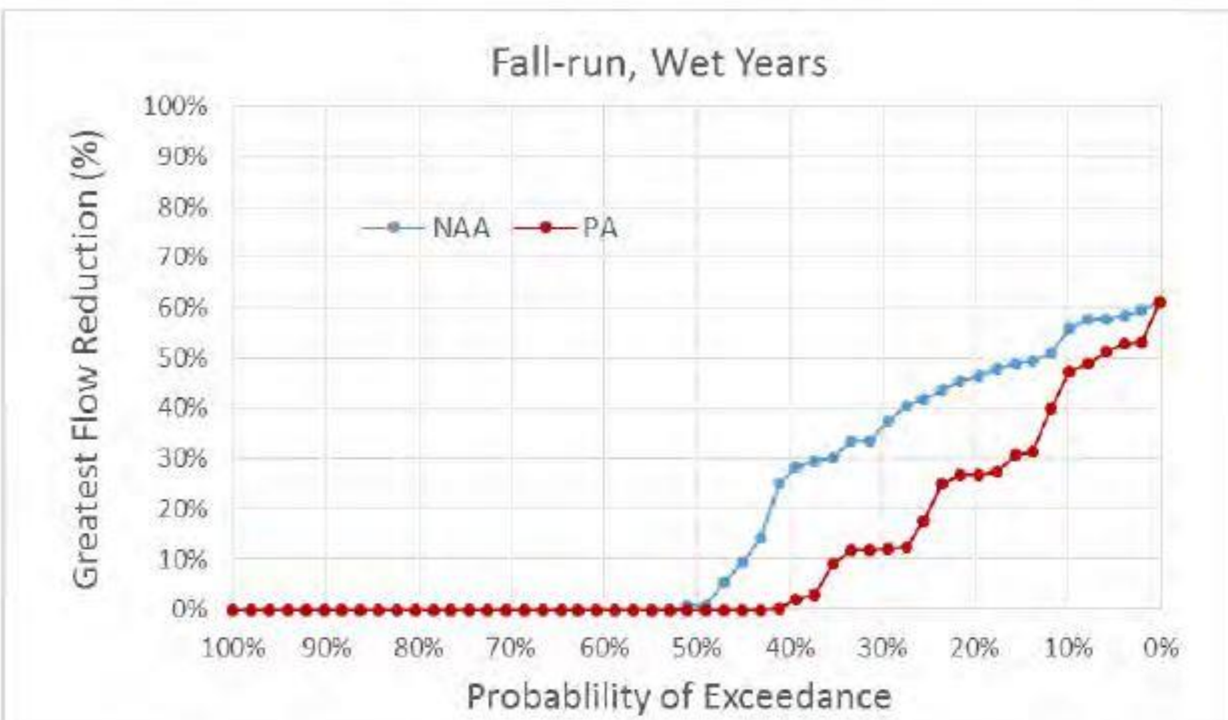

Figure ***Error! No text of specified style in document.****-72. Exceedance Plot of Maximum Flow Reductions (percent) for 3-Month Period after Fall-Run Chinook Salmon Spawning for NAA and PA Model Scenarios, Wet Water Years*

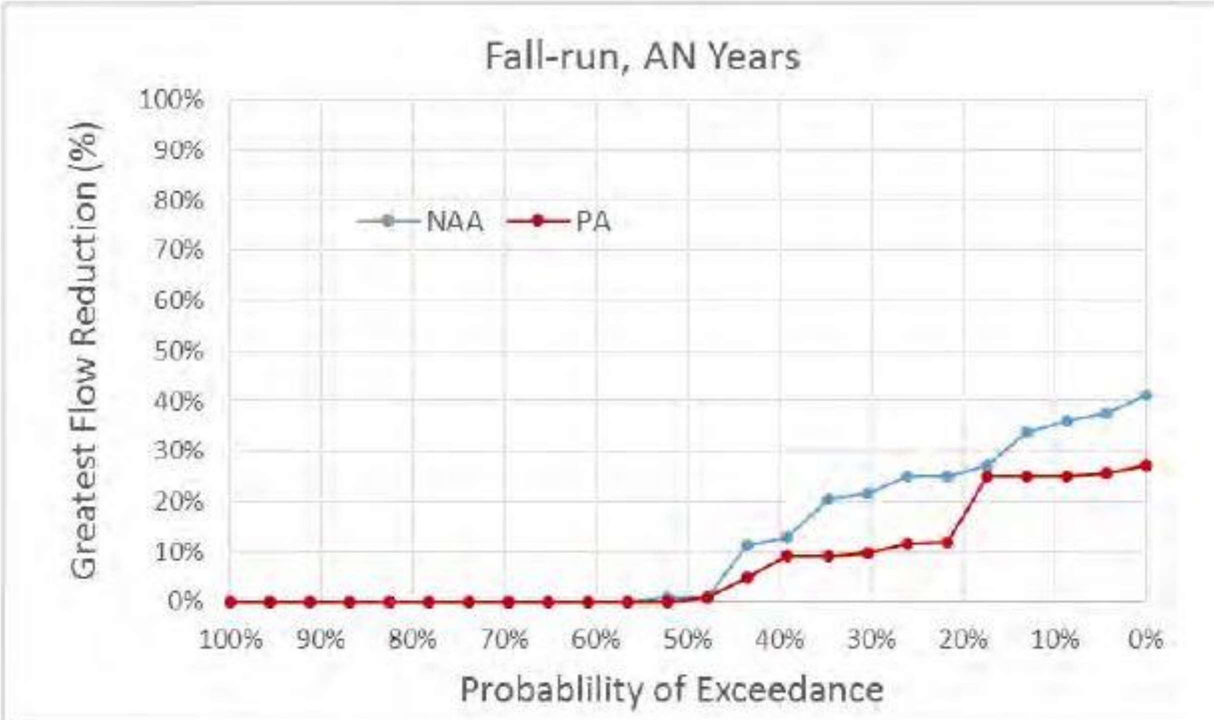

*Figure **Error! No text of specified style in document.**-73. Exceedance Plot of Maximum Flow Reductions (percent) for 3-Month Period after Fall-Run Chinook Salmon Spawning for NAA and PA Model Scenarios, Above Normal Water Years*

*Figure **Error! No text of specified style in document.**-74. Exceedance Plot of Maximum Flow Reductions (percent) for 3-Month Period after Fall-Run Chinook Salmon Spawning for NAA and PA Model Scenarios, Below Normal Water Years*

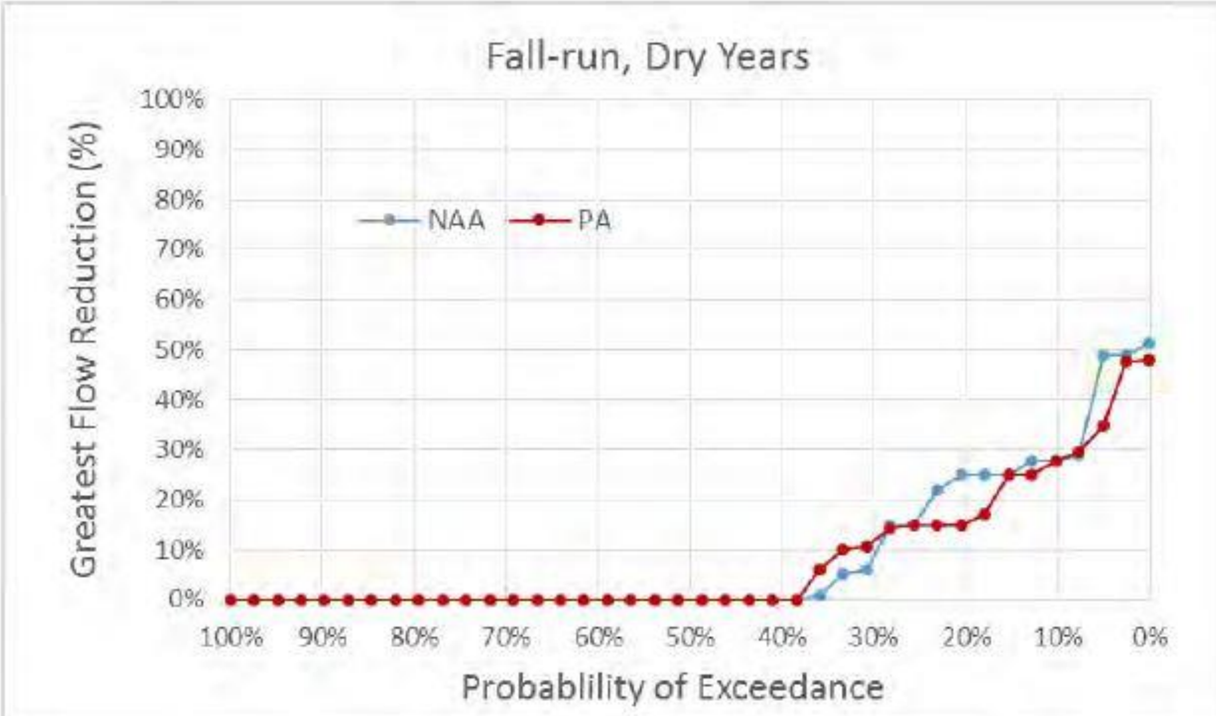

Figure ***Error! No text of specified style in document.****-75. Exceedance Plot of Maximum Flow Reductions for 3-Month Period after Fall-Run Chinook Salmon Spawning for NAA and PA Model Scenarios, Dry Water Years*

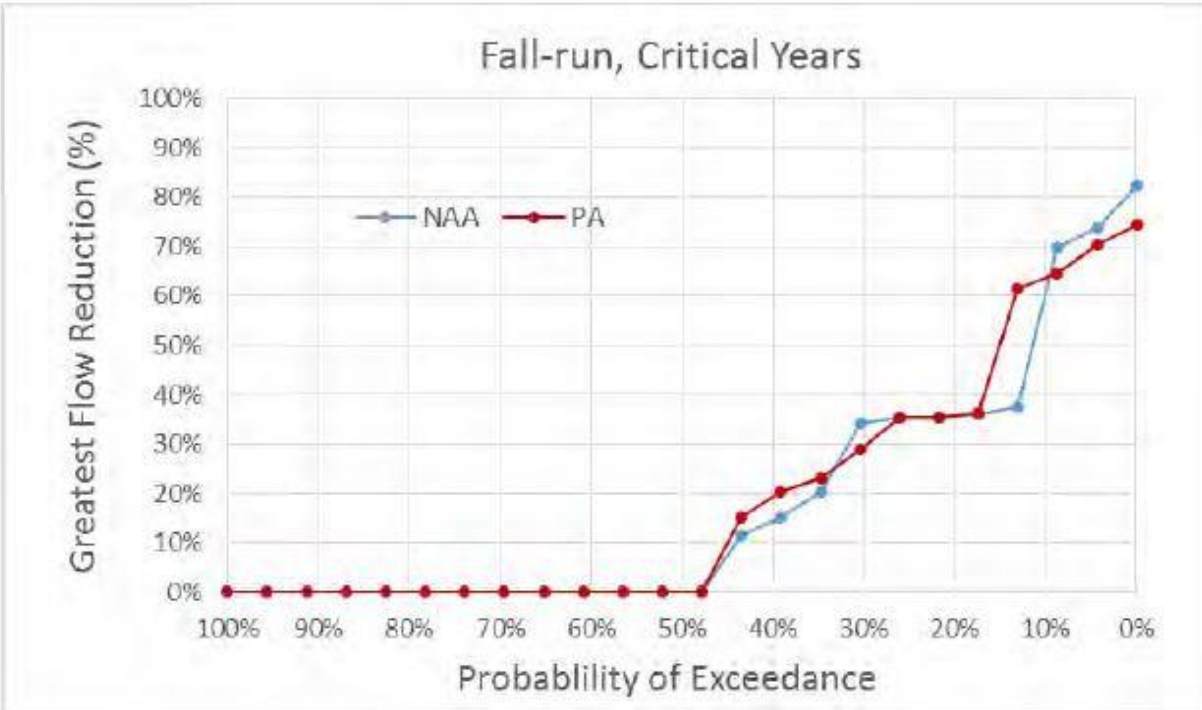

Figure ***Error! No text of specified style in document.****-76. Exceedance Plot of Maximum Flow Reductions for 3-Month Period after Fall-Run Chinook Salmon Spawning for NAA and PA Model Scenarios, Critical Water Years*

For the redd dewatering analysis in the BO, we take things one step further than the BA by assuming that a 25 percent reduction from the spawning flow will result in at least some redd dewatering, and a 50 percent reduction from the spawning flow will result in extensive redd dewatering. Making these general assumptions provides additional context for understanding how redd dewatering under the PA may impact fall-run Chinook salmon in the American River. The assumptions seem reasonable because: (1) fall-run Chinook salmon often spawn in shallow areas, which are more susceptible to being dewatered with a reduction in flow than deep areas; and (2) they are generally supported by the relationship between redd dewatering and flow for fall-run Chinook salmon on the Sacramento River with the ACID Dam boards out (Table 5.D-57 in the Appendix 5D of the BA). For example, 30 percent of all fall-run Chinook salmon redds would be dewatered on the Sacramento River if spawning flows of 10,000 cfs were reduced to 5,000 cfs after spawning (a 50 percent reduction from the spawning flow). A 25 percent drop in spawning flows would dewater 9 percent of all redds (Table 5.D-57 in the Appendix 5D of the BA). The percentage of time that 25 percent (at least some redd dewatering) or 50 percent (i.e. extensive redd dewatering) reductions in spawning flow would occur under the PA by water year type are shown in Table **Error! No text of specified style in document.**-33.

Table ***Error! No text of specified style in document.****-33. Percentage of time that 25 percent (at least some redd dewatering) or 50 percent (i.e. extensive redd dewatering) reductions in American River fall-run Chinook salmon spawning flow would occur during the egg and alevin life stages under the PA by water year type.*

Water Year Type	At Least Some Redd Dewatering	Extensive Redd Dewatering
Wet	24 percent	8 percent
Above Normal	18 percent	0 percent
Below Normal	19 percent	4 percent
Dry	15 percent	0 percent
Critical	34 percent	16 percent
All Years	23 percent	6 percent

At least some fall-run Chinook salmon redd dewatering is expected to occur in the American River in approximately 23 percent of all water years combined. Extensive redd dewatering is expected in 6 percent of the years. The most redd dewatering is expected in critical water years, with at least some dewatering occurring in 34 percent of critical years and extensive dewatering occurring in 16 percent of critical years. The least amount of redd dewatering is expected in dry years. Overall the magnitude of redd dewatering is medium given that at least some redd dewatering is expected in 15 to 34 percent of years, and extensive redd dewatering has a relatively low frequency of occurrence. The certainty of this medium magnitude ranking is low given that the specific relationship between American River flow and fall-run Chinook salmon redd dewatering is unknown, and there are limitations of using results based on monthly flows to understand the magnitude of impacts that occur over a daily time scale.

2.5.1.2.3 Redd Scour

Streambed scour resulting from high flows is a physical factor that can reduce salmonid egg survival and limit population productivity. High flows can mobilize sediments in the river bed causing direct egg mortality if scour occurs to the depth of the top of the egg pocket. Scour can also increase fine sediment infiltration and indirectly decrease egg survival (DeVries 1997).

This redd scour analysis directly incorporates the methods and results presented in the BA. The redd scour analysis primarily relies upon a flow analysis whereby the probability of flows occurring under the PA and the NAA that would be high enough to mobilize sediments and scour Chinook salmon and steelhead redds was estimated from CALSIM II estimates of mean monthly flows by applying a relationship determined from the historical record between actual mean monthly flow and maximum daily flow (BA Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*). The actual monthly and daily flow data used in the analysis are from gage records just below Keswick Dam and at Bend Bridge. CALSIM II estimates used to compare probabilities of redd scour for the PA and the NAA are for the Keswick Dam and Red Bluff locations. As discussed in Appendix 5.D, Section 5.D.2.2, *Spawning Flow Methods* of the BA, 40,000 cfs is treated as the minimum daily flow at which redd scour occurs in the Sacramento River. Analysis of the Keswick Dam gage data shows that for months with a mean monthly flow of at least

27,300 cfs, the maximum daily flow in that month is always at least 40,000 cfs. The Bend Bridge gage data show that for months with a mean flow of at least 21,800 cfs, the maximum daily flow in that month is always 40,000 cfs. Therefore, redd scour probabilities for the PA and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 27,300 cfs at Keswick Dam or greater than 21,800 cfs at Red Bluff during the respective spawning and incubation periods for winter-run Chinook salmon, spring-run Chinook salmon, steelhead, fall-run Chinook salmon, and late fall-run Chinook salmon. Further information on the redd scour analysis methods is provided in the BA in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Secondarily, redd scour impacts were assessed through SALMOD, which predicts "incubation" mortality as a combination of redd scour and dewatering. Because it is impossible to evaluate redd scour and dewatering independently through SALMOD, conclusions as to whether redd scour under the PA would adversely affect each species are based more so on the redd scour flow thresholds analysis.

2.5.1.2.3.1 Winter-run Exposure and Risk

The redd scour analysis suggests there is little risk to winter-run Chinook salmon resulting from high PA flows during the April through October spawning and egg incubation period. Table Error**! No text of specified style in document.**-34 shows that less than one percent of months in the CALSIM II record during the winter-run Chinook salmon spawning and incubation period would have flows of more than 27,300 cfs at Keswick Dam or more than 21,800 cfs at Red Bluff. Only one water year and month with mean monthly flow greater than 27,300 cfs was predicted at Keswick Dam for the winter-run spawning and incubation period (Table **Error! No text of specified style in document.**-35), and several water years and months with mean monthly flow greater than 21,800 cfs were predicted at Red Bluff (Table **Error! No text of specified style in document.**-36) under both the NAA and PA. For winter-run Chinook salmon, there would be no differences between the PA and the NAA in the percentage of scouring flows at either location.

*Table **Error! No text of specified style in document.**-34. Percent of Months during Spawning and Incubation Periods with CALSIM II Flow Greater than Redd Scouring Threshold Flow at Keswick Dam (27,300 cfs) and Red Bluff (21,800 cfs) between Model Scenarios*

Species/Race	Keswick Dam			Red Bluff		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Winter-run Chinook salmon	0.2	0.2	0 (0 percent)	0.7	0.7	0 (0 percent)

*Table **Error! No text of specified style in document.**-35. Water Year and Month with Mean Flow > 27,300 cfs at Keswick Dam During the Winter-run Chinook Salmon Spawning and Incubation Period*

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
1963	April	Wet	30,893	30,893

Table ***Error! No text of specified style in document.****-36. Water Years and Months with Mean Flow > 21,800 cfs at Red Bluff during the Winter-run Chinook Salmon Spawning and Incubation Period*

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
1941	April	Wet	24,464	24,464
1958	April	Wet	22,228	22,228
1963	April	Wet	42,184	42,182
1982	April	Wet	33,884	33,885

The SALMOD model provides predicted flow-related mortality of winter-run Chinook salmon eggs and alevins in the Sacramento River (see BA Attachment 5.D.2, *SALMOD Model* for a full description). The SALMOD results for this type of mortality are presented in (Table 2-40), together with results for the other sources of mortality of winter-run Chinook salmon predicted by SALMOD. The flow-related mortality of winter-run Chinook salmon eggs and alevins is split up as “incubation” (which refers to redd dewatering and scour) and “superimposition” (of redds) mortality. The annual exceedance plot of flow-related mortality of winter-run Chinook salmon eggs and alevins is presented in Figure Error**! No text of specified style in document.**-77. These results indicate that there would be increases in flow-related mortality of winter-run Chinook salmon eggs and alevins from incubation-related factors under the PA relative to the NAA for all water year types (increase in average annual mortality of 61,712 eggs and alevins, or 17 percent, for all water year types combined). Because the redd scour flow threshold analysis discussed above suggests that redd scour is expected to have little effect on winter-run Chinook salmon under either project scenario, the incubation-related mortality predicted by SALMOD, which combines redd scour and dewatering, is likely primarily attributable to redd dewatering.

Overall, redd scour under the PA is not expected to adversely affect winter-run Chinook salmon eggs, except for very rare cases (less than one percent of months).

*Table **Error! No text of specified style in document.**-37. Mean Annual Winter-Run Chinook Salmon Mortality1 (# of Fish/Year) Predicted by SALMOD*

Note: SALMOD showed zero flow-related mortality due to superimposition, zero Temperature and flow related mortality to immature smolts

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing									
	Temperature-Related Mortality			Flow-Related Mortality				Temperature-Related Mortality				Flow-Related Mortality					
Analysis Period	**Pre-Spawn**	**Eggs**	**Subtotal**	**Incubation**	**Super-imposition**	**Subtotal**	**Life Stage Total**	**Fry**	**Pre-smolt**	**Immature Smolt**	**Subtotal**	**Fry**	**Pre-smolt**	**Immature Smolt**	**Subtotal**	**Life Stage Total**	**Grand Total**
All Water Year Types[2]																	
NAA	9,092	423,231	432,323	368,939	0	368,939	801,262	5,343	2,391	0	7,734	123,789	115	0	123,904	131,638	932,900
PA	9,119	391,450	400,568	430,651	0	430,651	831,220	5,495	2,125	0	7,620	120,680	104	0	120,784	128,404	959,624
Difference	27	-31,781	-31,755	61,712	0	61,712	29,958	152	-266	0	-114	-3,109	-11	0	-3,120	-3,234	26,723
Percent Difference[3]	0	-8	-7	17	0	17	4	3	-11	0	-1	-3	-10	0	-3	-2	3
Water Year Types[4]																	
Wet (32.5%)																	
NAA	8,774	806	9,580	167,602	0	167,602	177,182	0	0	0	0	173,745	36	0	173,781	173,781	350,962
PA	8,890	670	9,560	244,211	0	244,211	253,771	0	0	0	0	154,086	27	0	154,113	154,113	407,884
Difference	116	-136	-19	76,609	0	76,609	76,589	0	0	0	0	-19,659	-9	0	-19,667	-19,667	56,922
Percent Difference	1	-17	0	46	0	46	43	0	0	0	NA	-11	-25	0	-11	-11	16
Above Normal (12.5%)																	
NAA	9,001	457	9,459	316,112	0	316,112	325,570	0	0	0	0	159,631	24	0	159,655	159,655	485,225
PA	9,001	376	9,378	369,936	0	369,936	379,313	0	0	0	0	139,838	16	0	139,854	139,854	519,167
Difference	0	-81	-81	53,824	0	53,824	53,743	0	0	0	0	-19,793	-8	0	-19,801	-19,801	33,942
Percent Difference	0	-18	-1	17	0	17	17	0	0	0	NA	-12	-32	0	-12	-12	7
Below Normal (17.5%)																	
NAA	7,909	8,021	15,930	587,438	0	587,438	603,368	10	1	0	11	95,189	127	0	95,316	95,327	698,696
PA	8,455	12,730	21,184	714,331	0	714,331	735,515	11	1	0	12	105,939	117	0	106,056	106,068	841,584
Difference	545	4,709	5,254	126,893	0	126,893	132,147	1	0	0	1	10,749	-10	0	10,740	10,741	142,888
Percent Difference	7	59	33	22	0	22	22	15	-8	0	12	11	-8	0	11	11	20
Dry (22.5%)																	
NAA	9,789	29,678	39,467	610,519	0	610,519	649,986	24	6	0	30	106,542	246	0	106,788	106,818	756,803
PA	9,474	21,650	31,123	648,552	0	648,552	679,676	25	4	0	29	122,973	182	0	123,155	123,184	802,859
Difference	-316	-8,028	-8,344	38,034	0	38,034	29,690	1	-2	0	-1	16,431	-64	0	16,367	16,366	46,056
Percent Difference	-3	-27	-21	6	0	6	5	5	-33	0	-3	15	-26	0	15	15	6
Critical (15%)																	
NAA	9,853	2,764,994	2,774,847	275,207	0	275,207	3,050,054	35,573	15,929	0	51,502	33,235	160	0	33,395	84,897	3,134,950
PA	9,779	2,561,888	2,571,667	290,273	0	290,273	2,861,940	36,581	14,162	0	50,743	39,024	223	0	39,247	89,990	2,951,930
Difference	-74	-203,106	-203,180	15,066	0	15,066	-188,113	1,008	-1,767	0	-759	5,789	63	0	5,852	5,093	-183,021
Percent Difference	-1	-7	-7	5	0	5	-6	3	-11	0	-1	17	40	0	18	6	-6

[1] Mortality values do not include base mortality

[2] Based on the 80-year simulation period

[3] Relative difference of the Annual average

[4] As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (State Water Resources Control Board 1995). Water years may not correspond to the biological years in SALMOD.

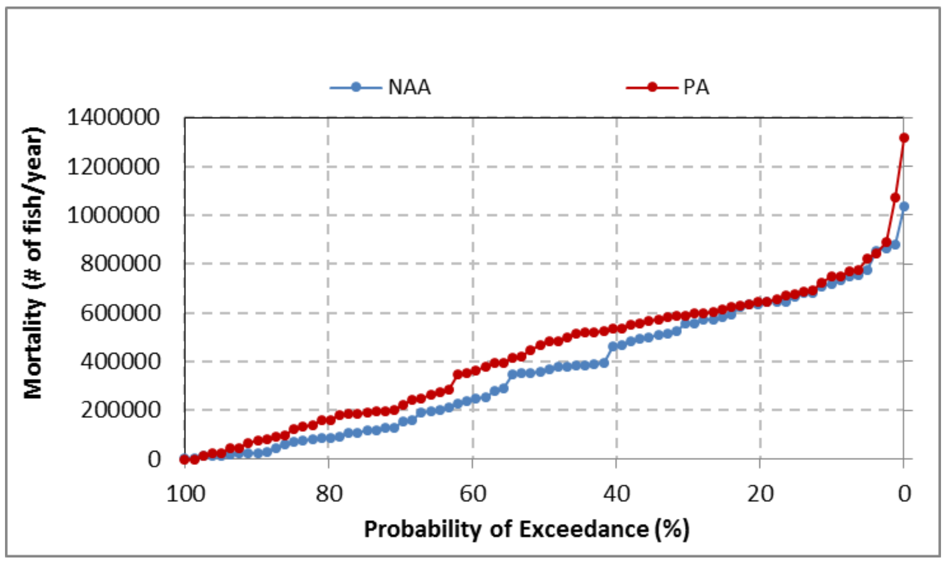

*Figure **Error! No text of specified style in document.**-77. Exceedance Plot of Annual Flow-Based Mortality (#of Fish/Year) of Winter-Run Chinook Salmon Spawning, Egg Incubation, and Alevins*

2.5.1.2.3.2 Spring-run Exposure and Risk

Table **Error! No text of specified style in document.**-38 shows that fewer than 3 percent of months in the CALSIM II record during the spawning and incubation period of spring-run Chinook salmon (August through December) would have flows of more than 27,300 cfs at Keswick Dam or more than 21,800 cfs at Red Bluff. This was expected, given that all of the months of the spring-run spawning and incubation period except December rarely experience such high flows. The difference between the PA and the NAA in the percentage of months with scouring flows is 0.2 percent at both locations.

*Table **Error! No text of specified style in document.**-38. Percent of Months during Spawning and Incubation Periods with CALSIM II Flow Greater than Redd Scouring Threshold Flow at Keswick Dam (27,300 cfs) and Red Bluff (21,800 cfs) between Model Scenarios*

	Keswick Dam			Red Bluff		
Species/Race	**NAA**	**PA**	**PA vs. NAA**	**NAA**	**PA**	**PA vs. NAA**
Spring-run Chinook salmon	0.7	0.5	-0.2 (-25 percent)	2.6	2.8	0.2 (7 percent)

The SALMOD model provides predicted flow-related mortality of spring-run Chinook salmon eggs and alevins in the Sacramento River (see BA Attachment 5.D.2, *SALMOD Model* for a full description). The SALMOD results for this type of mortality are presented in (Table 2-42), together with results for the other sources of mortality of spring-run Chinook salmon predicted by SALMOD. The flow-related mortality of spring-run Chinook salmon eggs and alevins is split up as “incubation” (which refers to redd dewatering and scour) and “superimposition” (of redds) mortality. Egg and alevin mortality attributable to redd scour and dewatering across all water year types is 2,118 under the PA, 212 higher than under the NAA (Table **Error! No text of specified style in document.**-39).

The annual exceedance plot of flow-related mortality of spring-run Chinook salmon spawning, eggs, and alevins is presented in Figure 2-80. These results indicate that there would be increases in flow-related mortality of spring-run Chinook salmon spawning, eggs, and alevins from incubation-related factors under the PA relative to the NAA for all water year types except dry years. The largest increases, about 30 percent, would be for wet, above normal and below normal water year types. Because the redd scour flow threshold analysis discussed above suggests that redd scour is expected to have little effect on spring-run Chinook salmon under either project scenario, the incubation-related mortality predicted by SALMOD, which combines redd scour and dewatering, is likely primarily attributable to redd dewatering.

*Table **Error! No text of specified style in document.**-39. Mean Annual Spring-Run Chinook Salmon Mortality[1] (# of Fish/Year) Predicted by SALMOD*

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing									
	Temperature-Related Mortality			Flow-Related Mortality				Temperature-Related Mortality				Flow-Related Mortality					
Analysis Period	**Pre-Spawn**	**Eggs**	**Subtotal**	**Incubation**	**Super-imposition**	**Subtotal**	**Life Stage Total**	**Fry**	**Pre-smolt**	**Immature Smolt**	**Subtotal**	**Fry**	**Pre-smolt**	**Immature Smolt**	**Subtotal**	**Life Stage Total**	**Grand Total**
All Water Year Types2																	
NAA	46,032	124,013	170,045	1,905	0	1,905	171,950	1	0	0	1	2,265	0	0	2,265	2,265	174,215
PA	50,462	107,473	157,935	2,118	0	2,118	160,053	0	0	0	0	2,273	0	0	2,273	2,273	162,325
Difference	4,431	-16,540	-12,110	212	0	212	-11,898	-1	0	0	-1	8	0	0	8	7	-11,890
Percent Difference[3]	10	-13	-7	11	0	11	-7	-100	0	0	-100	0	0	0	0	0	-7
Water Year Types4																	
Wet (32.5%)																	
NAA	116	6,530	6,646	1,336	0	1,336	7,983	0	0	0	0	2,614	0	0	2,614	2,614	10,597
PA	117	5,835	5,952	1,748	0	1,748	7,699	0	0	0	0	2,815	0	0	2,815	2,815	10,514
Difference	1	-695	-695	411	0	411	-283	0	0	0	0	200	0	0	200	200	-83
Percent Difference	0	-11	-10	31	0	31	-4	0	0	0	NA5	8	0	0	8	8	-1
Above Normal (12.5%)																	
NAA	78	4,181	4,258	1,162	0	1,162	5,420	0	0	0	0	2,703	0	0	2,703	2,703	8,124
PA	65	3,888	3,953	1,509	0	1,509	5,463	0	0	0	0	2,354	0	0	2,354	2,354	7,816
Difference	-12	-293	-305	347	0	347	42	0	0	0	0	-350	0	0	-350	-350	-307
Percent Difference	-16	-7	-7	30	0	30	1	0	0	0	NA	-13	0	0	-13	-13	-4
Below Normal (17.5%)																	
NAA	154	34,929	35,084	1,300	0	1,300	36,384	0	0	0	0	2,634	0	0	2,634	2,634	39,018
PA	309	41,242	41,551	1,711	0	1,711	43,262	0	0	0	0	2,591	0	0	2,591	2,591	45,853
Difference	155	6,313	6,467	411	0	411	6,878	0	0	0	0	-43	0	0	-43	-43	6,835
Percent Difference	100	18	18	32	0	32	19	0	0	0	NA	-2	0	0	-2	-2	18
Dry (22.5%)																	
NAA	1,093	66,312	67,406	3,652	0	3,652	71,058	0	0	0	0	2,468	0	0	2,468	2,468	73,526
PA	995	64,050	65,045	3,422	0	3,422	68,467	0	0	0	0	2,438	0	0	2,438	2,438	70,905
Difference	-98	-2,263	-2,361	-230	0	-230	-2,591	0	0	0	0	-30	0	0	-30	-30	-2,621
Percent Difference	-9	-3	-4	-6	0	-6	-4	0	0	0	NA	-1	0	0	-1	-1	-4
Critical (15%)																	
NAA	304,677	671,412	976,089	1,670	0	1,670	977,759	3	0	0	3	408	0	0	408	411	978,170
PA	334,238	560,737	894,976	1,835	0	1,835	896,811	0	0	0	0	463	0	0	463	463	897,274
Difference	29,562	-110,675	-81,113	165	0	165	-80,949	-3	0	0	-3	55	0	0	55	52	-80,897
Percent Difference	10	-16	-8	10	0	10	-8	-100	0	0	-100	14	0	0	14	13	-8

[1] Mortality values do not include base mortality
[2] Based on the 80-year simulation period
[3] Relative difference of the Annual average
[4] As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (State Water Resources Control Board 1995{ TC "SWRCB 1995" \f C \l "1" }). Water years may not correspond to the biological years in SALMOD.
[5] NA = Unable to calculate because dividing by 0

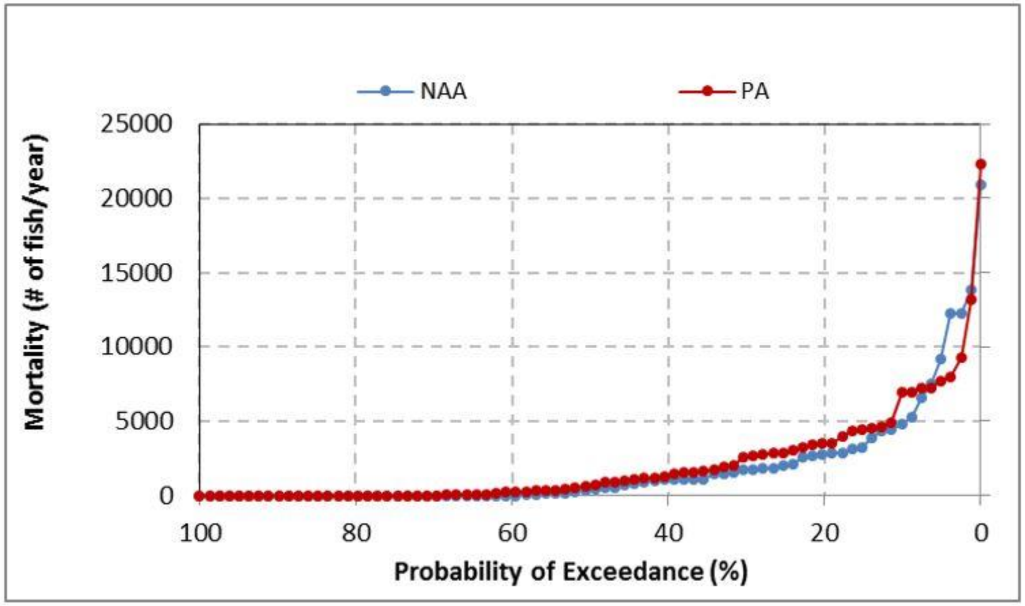

*Figure **Error! No text of specified style in document.**-78. Exceedance Plot of Annual Flow-Based Mortality (# of Fish/Year) of Spring-Run Chinook Salmon Spawning, Egg Incubation, and Alevins*

Overall, redd scour under the PA is not expected to adversely affect spring-run Chinook salmon eggs, except for rare cases (less than three percent of months).

2.5.1.2.3.3 Steelhead Exposure and Risk

2.5.1.2.3.3.1 Sacramento River

Table **Error! No text of specified style in document.**-40 shows that about 5 percent of months at Keswick Dam and about 15 percent of months at Red Bluff would have flows above the redd scouring thresholds during the November through April spawning and incubation period of Central Valley steelhead. The relatively high percentage of months with scouring flows in the steelhead spawning and incubation period is expected, given that the period encompasses the wettest months of the year. There would be no difference between the PA and the NAA in the percentage of months with scouring flows at Keswick Dam. The percentage of months with scouring flows at Red Bluff would be one percent higher under the PA than under the NAA.

*Table **Error! No text of specified style in document.**-40. Percent of Months during Spawning and Incubation Periods with CALSIM II Flow Greater than Redd Scouring Threshold Flow at Keswick Dam (27,300 cfs) and Red Bluff (21,800 cfs) between Model Scenarios*

Species/Race	Keswick Dam			Red Bluff		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
CCV Steelhead	5.3	5.3	0 (0 percent)	14.6	15.7	1 (7 percent)

2.5.1.2.3.3.2 American River

The probability of flows in the American River occurring under the PA and the NAA that would be high enough to mobilize sediments and scour Central Valley steelhead redds was estimated from CALSIM II estimates of mean monthly flows, using a relationship determined from the historical record between actual mean monthly and maximum daily flow (BA Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*).

Actual monthly and daily flow data used in the analysis are from gage records at Hazel Avenue and the CALSIM II estimates used to compare probabilities of redd scour for the PA and the NAA are for the Nimbus Dam location.

As discussed in the BA in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*, 40,000 cfs is treated as the minimum daily flow at which redd scour occurs in the American River. Analysis of Hazel Avenue gage data shows that for months with a mean monthly flow of at least 19,350 cfs, the maximum daily flow in that month is always at least 40,000 cfs. Therefore, redd scour probabilities for the PA and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 19,350 cfs at Nimbus during the steelhead December through May spawning and incubation period. Further information on the redd scour analysis methods is provided in the BA in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

*Table **Error! No text of specified style in document.**-41. Water Years and Months with Mean Flow >19,350 cfs at Hazel Avenue during the Central Valley Steelhead Spawning and Incubation Period in the American River*

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
1964	December	Dry	21,494	21,414
1968	January	Below Normal	23,260	23,929
1969	January	Wet	25,092	25,092
1983	March	Wet	19,927	19,927
1983	December	Wet	22,909	22,909
1986	February	Wet	37,305	37,305
1995	March	Wet	19,730	19,721
1996	January	Wet	38,218	38,218

2.5.1.2.3.4 Green Sturgeon Exposure and Risk

As stated previously, because sturgeon spawn in deep pools, the eggs adhere to bottom cobble and gravel substrates or settle into crevices, and their incubation time is relatively short (i.e., seven to nine days, they are less vulnerable to sediment mobilization under high flows than salmonid species are. Pools requiring higher flows to mobilize bed material than riffle/run material. Therefore, green sturgeon would experience little to no impacts from scour of their spawning areas.

2.5.1.2.3.5 Fall/Late fall-run Exposure and Risk

2.5.1.2.3.5.1 Sacramento River

2.5.1.2.3.5.1.1 Fall-run Chinook Salmon

Table **Error! No text of specified style in document.**-42 shows that about two percent of months at Keswick and about eight percent of months at Red Bluff would have flows above the redd scouring thresholds during the September through January spawning and incubation period of fall-run Chinook salmon. The moderately high percentage of scouring flows in the fall-run spawning and incubation period is expected, given that the period includes December and January, two of the wettest months of the year. The percentage of months with scouring flows under the PA would be about 0.2 percent lower at Keswick and 0.5 percent greater at Red Bluff.

*Table **Error! No text of specified style in document.**-42. Percent of Months during Fall-run Chinook Salmon Spawning and Incubation Period with CALSIM II Flow Greater than Redd Scouring Threshold Flow at Keswick (27,300 cfs) and Red Bluff (21,800 cfs) between Model Scenarios*

Species/Race	Keswick			Red Bluff		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Fall-run Chinook salmon	2.2	2.0	-0.2 (-11%)	7.8	8.3	0.5 (6%)
Late fall-run Chinook salmon	4.4	4.4	0 (0%)	12.4	13.1	0.7 (6%)

The SALMOD model provides predicted flow-related mortality of fall-run Chinook salmon eggs and alevins in the Sacramento River (see BA Attachment 5.D.2, *SALMOD Model* for a full description). The SALMOD results for this type of mortality are presented in Table Error**! No text of specified style in document.**-29, together with results for the other sources of mortality of fall-run Chinook salmon predicted by SALMOD. The flow-related mortality of fall-run Chinook salmon eggs and alevins is split up as "incubation" (which refers to redd dewatering and scour) and "superimposition" (of redds) mortality. Egg and alevin mortality attributable to redd scour and dewatering across all water year types is 1,477,164 under the PA, 25,504 higher than under the NAA (Table **Error! No text of specified style in document.**-29).

Overall, redd scour is expected to adversely affect fall-run Chinook salmon eggs and alevins.

2.5.1.2.3.5.1.2 Late Fall-run Chinook Salmon

Table **Error! No text of specified style in document.**-42 shows that about four percent of months at Keswick and 12 to 13 percent of months at Red Bluff would have flows above the redd scouring thresholds during the late fall-run Chinook salmon spawning and incubation period identified in the BA (December through June). The moderately high percentage of scouring flows in this period is expected, given that it includes the wettest months of the year. There would be no difference between the PA and the NAA in the percentage of months with scouring flows at Keswick and the percentage of months with scouring flows under the PA would be 0.7 percent greater at Red Bluff.

The SALMOD model provides predicted flow-related mortality of late fall-run Chinook salmon eggs and alevins in the Sacramento River (see BA Attachment 5.D.2, *SALMOD Model* for a full description). The SALMOD results for this type of mortality are presented in Table 5.E-54, together with results for the other sources of mortality of late fall-run Chinook salmon predicted by SALMOD. The flow-related mortality of late fall-run Chinook salmon eggs and alevins is split up as "incubation" (which refers to redd dewatering and scour) and "superimposition" (of redds) mortality. Egg and alevin mortality attributable to redd scour and dewatering across all water year types is 172,486 under the PA, 2,072 higher than under the NAA.

*Table **Error! No text of specified style in document.**-43. Mean Annual Late Fall-Run Chinook Salmon Mortality1 (# of Fish/Year) Predicted by SALMOD*

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing									
	Temperature-Related Mortality			Flow-Related Mortality				Temperature-Related Mortality				Flow-Related Mortality					
Analysis Period	Pre-Spawn	Eggs	Subtotal	Incubation	Super-imposition	Subtotal	Life Stage Total	Fry	Pre-smolt	Immature Smolt	Subtotal	Fry	Pre-smolt	Immature Smolt	Subtotal	Life Stage Total	Grand Total
All Water Year Types[1]																	
NAA	0	9,621	9,621	170,413	310,055	480,468	490,089	3,759	68,139	38,185	110,083	1,776,744	14,419	567	1,791,729	1,901,812	2,391,902
PA	0	9,608	9,608	172,486	316,959	489,444	499,052	4,467	73,593	37,878	115,939	1,782,912	13,171	524	1,796,606	1,912,545	2,411,597
Difference	0	-14	-14	2,072	6,904	8,976	8,962	708	5,454	-306	5,856	6,168	-1,248	-43	4,877	10,733	19,695
Percent Difference[3]	0	0	0	1	2	2	2	19	8	-1	5	0	-9	-8	0	1	1
Water Year Types[2]																	
Wet (32.5%)																	
NAA	0	11,882	11,882	482,104	814,510	1,296,614	1,308,495	64	16	11	91	1,524,182	4,222	69	1,528,473	1,528,563	2,837,059
PA	0	11,880	11,880	486,545	824,230	1,310,775	1,322,656	63	20	5	88	1,502,838	3,095	69	1,506,002	1,506,090	2,828,746
Difference	0	-1	-1	4,441	9,720	14,162	14,160	-1	4	-6	-3	-21,344	-1,128	1	-22,471	-22,473	-8,313
Percent Difference	0	0	0	1	1	1	1	-1	28	-57	-3	-1	-27	1	-1	-1	0
Above Normal (12.5%)																	
NAA	0	7,815	7,815	22,967	370,137	393,103	400,918	110	37	19	166	1,843,097	1,583	28	1,844,708	1,844,874	2,245,792
PA	0	7,340	7,340	23,302	395,912	419,214	426,554	108	9	0	117	1,776,429	2,595	36	1,779,061	1,779,178	2,205,732
Difference	0	-475	-475	335	25,775	26,110	25,636	-2	-28	-19	-48	-66,668	1,012	8	-65,647	-65,696	-40,060
Percent Difference	0	-6	-6	1	7	7	6	-2	-75	-100	-29	-4	64	28	-4	-4	-2
Below Normal (17.5%)																	
NAA	0	1,186	1,186	30,443	0	30,443	31,630	0	872	2,684	3,556	1,958,331	16,897	713	1,975,940	1,979,496	2,011,126
PA	0	3,836	3,836	30,838	0	30,838	34,674	2	2,136	5,243	7,380	2,076,131	10,865	707	2,087,704	2,095,084	2,129,758
Difference	0	2,649	2,649	395	0	395	3,044	2	1,264	2,558	3,824	117,800	-6,032	-5	111,763	115,588	118,632
Percent Difference	0	223	223	1	0	1	10	0	145	95	108	6	-36	-1	6	6	6
Dry (22.5%)																	
NAA	0	10,840	10,840	29,324	0	29,324	40,163	137	4,347	8,912	13,396	1,868,390	9,467	824	1,878,681	1,892,076	1,932,240
PA	0	10,538	10,538	30,352	0	30,352	40,890	101	4,144	8,692	12,937	1,898,772	13,579	938	1,913,290	1,926,227	1,967,117
Difference	0	-301	-301	1,028	0	1,028	727	-36	-203	-220	-459	30,383	4,112	114	34,609	34,151	34,878
Percent Difference	0	-3	-3	4	0	4	2	-26	-5	-2	-3	2	43	14	2	2	2
Critical (15%)																	
NAA	0	12,420	12,420	31,960	0	31,960	44,380	24,592	446,147	237,209	707,948	1,917,364	54,477	1,579	1,973,420	2,681,368	2,725,748
PA	0	10,879	10,879	34,110	0	34,110	44,990	29,370	481,708	233,221	744,298	1,910,995	46,172	1,099	1,958,266	2,702,564	2,747,554
Difference	0	-1,541	-1,541	2,151	0	2,151	610	4,779	35,560	-3,989	36,350	-6,369	-8,305	-481	-15,154	21,196	21,806
Percent Difference	0	-12	-12	7	0	7	1	19	8	-2	5	0	-15	-30	-1	1	1

1 Based on the 80-year simulation period
2 As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB 1995). Water years may not correspond to the biological years in SALMOD.
3 Relative difference of the Annual average
4 Mortality values do not include base mortality

2.5.1.2.3.5.2 American River

The probability of flows in the American River occurring under the PA and the NAA that would be high enough to mobilize sediments and scour fall-run Chinook salmon redds was estimated from CALSIM II estimates of mean monthly flows, using a relationship determined from the historical record between actual mean monthly and maximum daily flow (BA Appendix 5.D.2.2, *Spawning Flow Methods*). Actual monthly and daily flow data used in the analysis are from gage records at Hazel Avenue, and the CALSIM II estimates used to compare probabilities of redd scour for the PA and the NAA are for the Nimbus Dam location. As discussed in the BA in Appendix 5.D.2.2, *Spawning Flow Methods*, 40,000 cfs is treated as the minimum daily flow at which redd scour occurs in the American River. Analysis of the Hazel Avenue gage data shows that for months with a mean monthly flow of at least 19,350 cfs, the maximum daily flow is always at least 40,000 cfs. Therefore, redd scour probabilities for the PA and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 19,350 cfs at Nimbus during the fall-run Chinook salmon October through January spawning and incubation period. Further information on the redd scour analysis methods is provided in the BA in Appendix 5.D.2.2, *Spawning Flow Methods*.

2.5.1.2.4 Stranding

Rapid reductions in flow can adversely affect fish. Juvenile salmonids are particularly susceptible to stranding during rapid reductions in flow. Stranding can occur when the rate of reductions in stream flow inhibits an individual's ability to escape an area that becomes isolated from the main channel or dewatered (U.S. Fish and Wildlife Service 2006). The effect of juvenile stranding on production of Chinook salmon and steelhead populations is not well understood, but stranding is frequently identified as a potentially important mortality factor for the populations in the Sacramento River and its tributaries (Jarret and Killam 2014, 2015, Cramer Fish Sciences 2014, National Marine Fisheries Service 2009, Bureau of Reclamation 2008, Water Forum 2005, California Department of Fish and Game 2001, U.S. Fish and Wildlife Service 2001).

Juveniles typically rest in shallow, slow-moving water between feeding forays into swifter water. These shallower, low-velocity margin areas are more likely than other areas to dewater and become isolated with flow changes (Jarrett and Killam 2015). Accordingly, juveniles are most vulnerable to stranding during periods of high and fluctuating flow when they typically move into inundated side channel habitats. Stranding can lead to direct mortality when these areas drain or dry up or to indirect mortality from predators or rising water temperatures and deteriorating water quality.

Different water management and water use actions can cause stranding. High, rapidly changing flows that then quickly decrease may result from flow release pulses to meet Delta water quality standards, from flood control releases, or from tributary freshets following rain events (Jarrett and Killam 2015, Bureau of Reclamation 2008). Stranding may also occur during periods of controlled flow reductions, such as when irrigation demand declines in the fall (National Marine Fisheries Service 2009) or following gate removal at the ACID dam in November (National Marine Fisheries Service 2009).

Stranding is currently a potential stressor in the upper Sacramento River, though mechanisms such as ramping restrictions exist that are intended to reduce the risk of occurrence. The upper Sacramento River has numerous side channel-like gravel bars that are used by juveniles as resting stops when inundated by higher flows. These areas can become isolated pools or even completely dewatered when reservoir releases are reduced. Although the NMFS biological opinion on the long-term operations of the CVP/SWP (National Marine Fisheries Service 2009) includes ramping restrictions for reservoir releases, CDFW rescues fish from these channel margin pools every year (CDFW 2013, 2014, 2015, 2016). CDFW monitoring reports show a range of numbers of different species and runs of anadromous fish observed and rescued in these efforts. The dependence of stranding risk on factors such as rate of sediment mobilization, rate of sediment settling in channel margin areas, and timing and rate of flow reductions makes the quantification of stranding risk difficult.

Juvenile stranding risk would likely remain during operations of the proposed action, but the magnitude is difficult to predict. Juvenile stranding generally results from reductions in flow that occur over short periods of time. The stranding analysis in the biological assessment uses the monthly flow results provided by CALSIM modeling of PA operations. This monthly time step is too coarse for a meaningful analysis of the short-term drivers of juvenile stranding. Though all ramping restrictions for dams on the Sacramento River and its tributaries would be kept in place for the PA, reservoir releases may vary from year to year in timing of flow fluctuations. There is therefore uncertainty to the level of effect of possible stranding on fish. Continued monitoring will be vital to understanding the level of effect and identifying additional minimization measures as needed.

2.5.1.2.4.1 Winter-run Species Exposure and Risk

Timing and distribution of juvenile winter-run presence in the upper Sacramento River is described in Section 2.5.1.2.1.

Juvenile winter-run Chinook salmon have the potential to be stranded, and thus adversely affected if resting in channel margin pools of the upper Sacramento River when flows are reduced. In order to preserve carry-over storage in the CVP reservoir releases are reduced October through April based on the CVPIA Anadromous Restoration Plan which targets minimum flows between 3,250 and 5,500 cfs in the fall. Between 1998 and 2000, and as part of the CVPIA Instream Flow Investigations, the USFWS identified 92 locations between Keswick Dam and Battel Creek which would potentially become isolated from the main channel at flows ranging from 3,250 cfs to 15,000 cfs (USFWS 2006). Modeled Keswick/ Shasta reservoir operations under the PA are not substantially different from the NAA scenario and therefore continue the risk of flow fluctuations in the river reaches below Keswick Dam that can strand winter-run. The potential for stranding would also persist under either the NAA or the PA as operations continue to target lower reservoir releases in the fall and winter to maximize carry-over storage. For operation of the CVP, this potential stranding has been largely mitigated by maintaining flows above 3,750 cfs and by implementing gradual ramping rates. However, NMFS expects that stranding of winter-run juveniles will continue due to reservoir operations under the PA and will adversely affect exposed individuals.

2.5.1.2.4.2 Spring-run Species Exposure and Risk

Timing of juvenile spring-run presence in the upper Sacramento River has previously been described in section *2.5.1.2.1 Increased Upstream Temperature*.

Juvenile spring-run Chinook salmon may potentially be adversely affected if resting in channel margin pools of the upper Sacramento River when flows are reduced. Annual aerial redd surveys on the Sacramento River (CDFW unpublished data 2016) in September indicate some spring-run

Chinook salmon spawning on the mainstem of the river, though numbers are low; surveys suggest from zero to 100 individuals. The majority of spring-run Chinook salmon hatch in the tributaries to the Sacramento River and then use the Sacramento River as a migratory corridor on route to the ocean. CDFW monitoring of fish stranded in isolated pools on the Sacramento River often cannot identify stranded juvenile spring-run Chinook salmon from fall-run Chinook salmon because of the spatial and temporal overlap of the two runs' spawning and subsequent juvenile outmigration. Mid-summer through winter monitoring indicates that Chinook salmon identified as spring-run/fall-run (based on length-at-date criteria) have been stranded. Six stranded spring-run were documented in 2015/2016 (CDFW 2013, 2014, 2015, 2016). Because the fall-run Chinook salmon ESU abundance is much greater than the CV spring-run Chinook salmon ESU, total numbers of stranded spring-run/fall-run are likely comprised of proportionately more fall-run Chinook salmon than spring-run Chinook salmon. The PA is unlikely to increase the risk of stranding to spring-run Chinook salmon on the Sacramento River.

2.5.1.2.4.3 Steelhead Species Exposure and Risk

Juvenile and adult steelhead have the potential to be isolated from the main channel of the Sacramento River or American River in side channels as river flows fluctuate and these waterbodies become separated from the main channel flow. Potential for stranding is typically greater for juveniles than for adults because of behavioral use of these habitats for rearing. Survival of juveniles and adults in stranding sites on these rivers depends on many factors. The connectivity to the river changes as reservoir releases change or as tributary flows change so each stranding site is a dynamic balance of environmental inputs at any given time. On the Sacramento River, the farther upstream the site, the less likely that downstream tributary flows will contribute to connectivity changes and stranding events are closely tied to reservoir releases. In the lower survey reaches, tributaries are influenced by precipitation events, and mainstem river levels can fluctuate quickly in response to these tributary flows even when reservoir releases are stable at Keswick. On the American River, there are no tributaries of significant size that would substantially influence river flow levels compared to reservoir releases from Folsom and Nimbus dams.

Annual surveys are conducted by fisheries agencies from Keswick Dam downstream to Tehama on the Sacramento River, a distance of 73 river miles (Killiam and Revnak 2016, Jarrett and Killiam 2015, 2014). Approximately 75 surveys are conducted each year and potential redd dewatering and stranding sites are identified during each survey. Over the past three seasons (2013–2014, 2014–2015, and 2015–2016) approximately 170-190 potential stranding locations have been identified each season in the 73-mile survey area. Typically about 30 of these locations are completely isolated from the main channel and have had salmonids entrapped in them.

Fish rescues conducted in these isolated waterbodies have recovered rainbow trout/ steelhead juveniles. The numbers of rainbow trout/steelhead rescued in the following seasons are:

- 2015–2016 season 15 fish,
- 2014–2015 season 515 fish, and
- 2013–2014 season 153 fish (CDFW 2014, 2015, 2016).

The actual numbers of fish stranded in these isolated pools and waterbodies are potentially much greater because of the inefficiency of the rescues in habitats that are not conducive to the rescue techniques (trees, rocks, and debris interfere with the seine nets, electroshocking, etc.) and the potential for predation and scavenging of trapped and dying fish isolated in these waterbodies.

It is also expected that reservoir releases on the American River from Folsom and Natomas reservoirs will create the potential for stranding of steelhead fry and juveniles in side channels and isolated pools on the American River. Under both the NAA and PA scenarios, reservoir releases increase substantially from January to February and then decline substantially from March through April, creating the potential for stranding and isolation in side channels and pools of newly emerged steelhead alevins and fry and older juvenile steelhead.

Modeled reservoir releases on the American River from Nimbus Dam indicate that there is a tendency for greater reductions in flow under the PA in certain months and water year types than under the NAA scenario. This has the potential to enhance the vulnerability to stranding of steelhead in the lower American River due to the PA.

2.5.1.2.4.4 Green Sturgeon Species Exposure and Risk

Stranding of green sturgeon does not occur in the mainstem Sacramento River, but reduced flows may nevertheless contribute to the stranding of juveniles and post-spawn adults on the seasonally inundated Yolo Bypass.

2.5.1.2.4.5 Fall/Late fall-run Species Exposure and Risk

2.5.1.2.4.5.1 Sacramento River

Fall-run Chinook salmon juveniles in the Sacramento River are vulnerable to becoming isolated in off channel habitats following flow reductions during their December through June fry and juvenile rearing period; late fall-run Chinook salmon juveniles are vulnerable during March through January. Juvenile stranding of fall-run and late fall-run Chinook salmon has been documented in the Sacramento River under current operations, despite the existence of criteria intended to slow flow reduction rates and allow juveniles to avoid being stranded.

CDFW has implemented juvenile stranding surveys in recent years in part to observe and report on locations that could potentially contain stranded salmonids that were isolated to varying degrees by flow reductions. Fish rescues have become an essential component of these surveys. During monitoring in the summer of 2015 through spring of 2016, 180 stranding locations between the Keswick Dam (the uppermost limit of anadromy on the Sacramento River) and the Tehama Bridge (a total of 73 river miles) were observed. A total of 6,748 fall/spring-run Chinook and late fall-run Chinook juveniles were observed stranded and rescued by crews during the 2015-2016 season (Stompe et al. 2016). During the 2013 through 2014 monitoring season, 188 stranding locations between the Keswick Dam and the Tehama were observed (Jarrett and Killam 2014). An estimated 6,360 naturally spawned Chinook juveniles were observed stranded in isolated sites. Of these, crews estimated that 232 fall-run juveniles were unlikely to survive their stranding due to environmental conditions. Crews were uncertain of the survival of the remaining fish. Rescue efforts were initiated beginning in January 2014 after CDFW rescue permitting was granted. Several thousand fish were successfully rescued including 6,551 juvenile Chinook salmon and rainbow trout/steelhead (Jarrett and Killam 2014). This monitoring shows that the stranding of thousands of juvenile salmonids, many of which are fall-run Chinook salmon, is a regular occurrence in the Sacramento River.

Given that the expected flows in the Sacramento River under the PA and NAA are largely similar, as the monthly modeled flow results suggest, the adverse effects on fry and juveniles related to flow reductions are expected to be similar between the PA and NAA.

2.5.1.2.4.5.2 American River

Fall-run Chinook salmon fry and juveniles occur in the American River from December through June. During that time they are vulnerable to fry stranding on dewatered gravel bars and juvenile isolation in off-channel habitats following reductions in flow. Numerous occurrences of both fall-run Chinook salmon fry stranding and juvenile isolation have been documented in the American River (CDFW 2001; Water Forum 2005). Because the PA does not include operational changes beyond existing ramp down criteria designed to minimize the rate of flow reductions within the American River, it is assumed that flow fluctuations and associated fry stranding and juvenile salmonid isolation that currently occur in the American River will also occur under PA operations. Therefore, flow fluctuations and associated impacts on juveniles under the PA are expected to result in adverse effects to juvenile fall-run Chinook salmon. Given that the expected flows in the American River under the PA and NAA are largely similar, as the monthly modeled flow results suggest, the adverse effects on fry and juveniles related to flow reductions are expected to be similar between the PA and NAA.

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